

The AMSAT[®] Journal

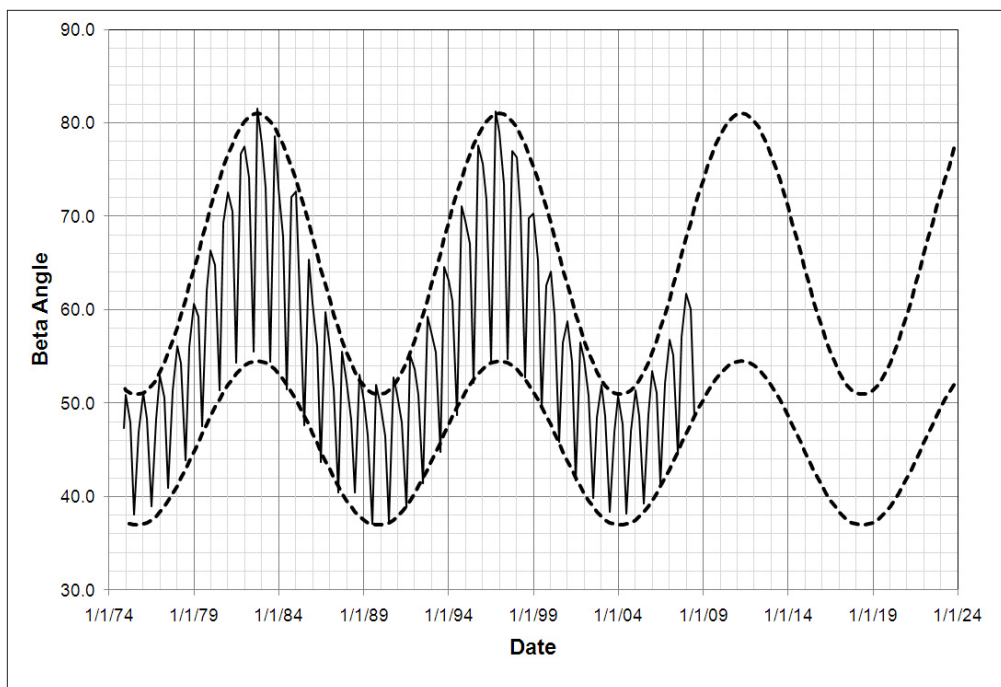


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Volume 33, Number 1

January/February 2010



Do you know your beta angle?



Hamfest season is here! Get out there and demo.

in this issue

AMSAT Announcements	2
Apogee View	3
<i>by Barry Baines • WD4ASW</i>	
AO-7 - 35 Years in Space:	4
Solar Array Power	
<i>by James A. DeYoung • N8OQ</i>	
Thoughts on the Magic of AO-7 ..	16
<i>by Tim Lilley • N3TL</i>	
AMSAT Telemetry	23
2010 AMSAT Field Day	25
Competition	
<i>by Bruce Paige • KK5DO</i>	
Go West Young Man	28
<i>by George Karr • WA5KBH</i>	
Successful AMSAT Activities	30
at the 2010 Greater Houston Hamfest	
<i>by Allen Mattis • N5AFV</i>	
FUNcube Press Notice	31
<i>by Graham Shirville • G3VZV</i>	

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Call for Papers--2010 ARRL/TAPR Digital Communications Conference

Technical papers are solicited for presentation at the 29th Annual ARRL and TAPR Digital Communications Conference to be held September 24-26, 2010 in Portland, Oregon. These papers will also be published in the Conference Proceedings (you do NOT need to attend the conference to have your paper included in the Proceedings). The submission deadline is July 31, 2010. Please send papers to:

Maty Weinberg
ARRL
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Newington, CT 06111

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Papers will be published exactly as submitted and authors will retain all rights.

73 . . . Steve, WB8IMY

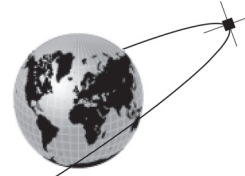
ARRL 

AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.



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Spring is finally approaching after many of us in the northeast and mid-Atlantic regions have 'enjoyed' a very challenging winter. Along with record snowfall in the mid-Atlantic, even Florida has suffered cooler temperatures. The Orlando Hamcation (12-14 February 2010) was impacted by unseasonable weather, as the AMSAT Forum was held in the 'Bubble House', an open enclosure where attendees huddled in 40°F windy conditions. There were about 30 hardy souls who attended the Forum that included details on ARISSat-1 provided by Gould Smith, WA4SXM, and Lou McFadin, W5DID, as well as an overview provided by AMSAT VP-Operations Drew Glasbrenner, KO4MA, of Amateur Radio's newest satellites, SO-67 (SumbandilaSat) and HO-68 (Hope).

Many thanks to Dave Jordan, AA4KN, who led the AMSAT booth operations at Hamcation and to the volunteers who manned the satellite station at the booth. Dave borrowed the Lake Monroe Amateur Radio Society 'satellite trailer' and setup a fully functional station on site. John Papay, K8YSE, and Doug Papay, KD8CAO, demonstrated remote operation of a satellite station by controlling John's satellite station in North Royalton, OH from the AMSAT booth at Hamcation, making several satellite contacts in the process. Orlando continues to grow in stature as one of the major hamfests in the southeast and Dave's team had a very successful weekend, selling out of several items and attracting a great deal of interest. As a former Floridian, I always enjoy Hamcation as a place to see old friends and have an opportunity to meet/greet AMSAT members.

Spring represents a period of rejuvenation and renewal and this year is no exception, even for AMSAT. Much has happened over the past quarter, but we also look forward to new opportunities. First, let me briefly review some recent events and provide some perspective.

AMSAT Acceptable User Policy (AUP)

After several months of development of a set of recommendations by a team led by Steve Belter, N9IP, the AMSAT Board of Directors adopted an Acceptable User Policy in January. As I'm writing this, a copy of this policy may be downloaded from the AMSAT Web site main page (www.amsat.org).

The purpose of this policy is to establish

acceptable behavior for the AMSAT public mailing lists. This policy was developed in response to several realizations:

1. AMSAT, as the provider of these services, is painted by the inappropriate behaviors of certain individuals. This not only impacts our reputation and has consequences for our relationships with other organizations who observe the interaction that takes place on our public mailing lists.
2. The behavior of individuals has a potential impact on other users of our public mailing lists. To encourage discussion and exchange of content that is related to areas of interest pertaining to AMSAT, we must define what constitutes the purpose of these lists.
3. The only way to establish appropriate behavior is to define what constitutes such behavior.
4. Most users expect establishment of an acceptable use policy. Other providers of electronic services have established their own documented policy statements. AMSAT is following precedent in creating our own policy.

Our greatest concern is that users of our services be treated with dignity and respect and the recognition that certain topics outside of acceptable content and behavior are to be discouraged. We live in a widely connected, diverse community of several thousand individuals around the world who have joined our services because of a common interest in Amateur Radio in space as well as AMSAT as an organization. The AUP recognizes that we all should be mindful of how we treat one another and the need to stay on topic.

My thanks to Steve, N9IP, and his team of volunteers who spent considerable time developing the AUP: Mark Hammond, N8MH; Alan Biddle, W4SCA; and Samudra Haque, N3RDX.

ARISSat-1

A critical design and safety review of ARISSat-1 was held in Orlando, FL following the Orlando Hamcation. This meeting included a spacecraft safety overview,

continued on page 18 ...



AO-7 – 35 Years in Space: Solar Array Power

by James A. DeYoung, N8OQ, n8oq@arri.net

Abstract

As of 14 November 2009, AO-7 had been in orbit for 35 years. The satellite continues to provide linear transponder-based communication service to licensed Amateur Radio operators worldwide. Spare, non-flight photovoltaic solar panels from the National Aeronautics and Space Administration Orbiting Geophysical Observatory program formed the basis for the construction of the AO-7 solar power system. This paper will present information concerning the origins, construction and related performance details of the solar array. Evaluation of a standard radiation degradation model gives a 33% loss for maximum power, a 15% loss for maximum power voltage, and a 23% loss in solar array current output for AO-7 after 35 years of exposure in its radiation environment. Telemetry giving the electrical current outputs from four solar array quadrants were received and decoded by several Amateur Radio service stations during March 2009. The telemetry was of good enough quality in several instances to allow determination

of the radiometer-based spin (roll) rates. The average of all 24 spin period determinations from the March 2009 interval was 11.0 +/- 1.6 minutes (0.091 revolutions per minute) with peak-to-peak values ranging from 8.9 minutes to 14.5 minutes. Several selected passes of AO-7 solar array quadrant DC

after the battery failure, Pat Gowen, G3IOR, found the AO-7 2 m beacon transmitting Morse code telemetry [2]. Since 2002 AO-7 has been used by licensed radio amateurs for communication through the two linear transponder systems that are available.

Since the 2002 recovery, AO-7 has been

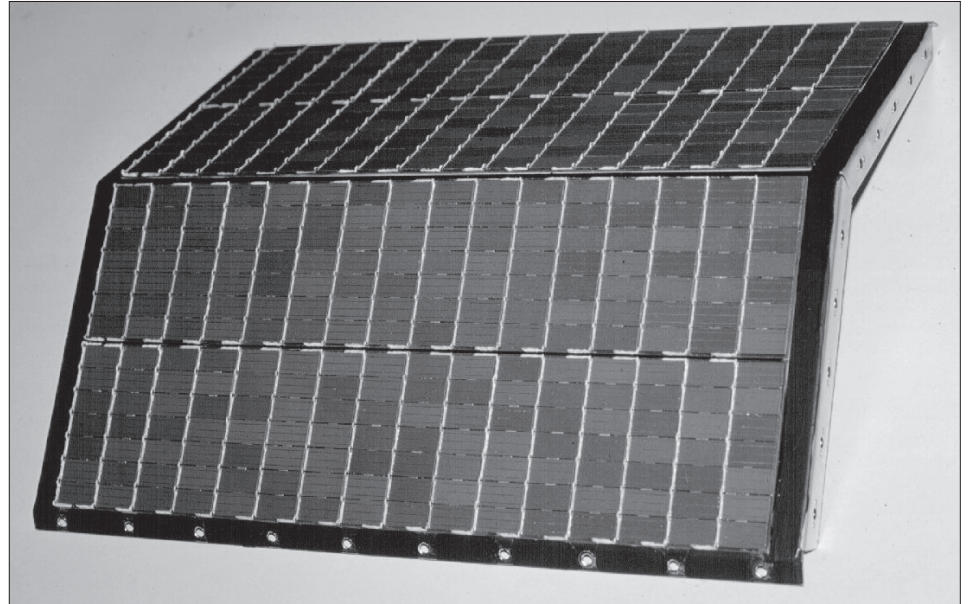


Figure 2: This is an image of AO-7 showing a solar array quadrant, one of four on the spacecraft. A quadrant is made up of two facets with a facet made up of two OGO panels. One panel is made up of 112 individual cells wired 7 in parallel and 16 in series. Electrical currents are reported in the RTTY telemetry stream are the output from each of the four quadrants. Other hardware details are visible, for example, in the upper panel small bumps are observable in the metal strips between solar cell rows which are thermal stress flex bumps to allow physical stress relief during transitions between eclipse and full sun (Photo credit Dick Daniels, W4PUJ).

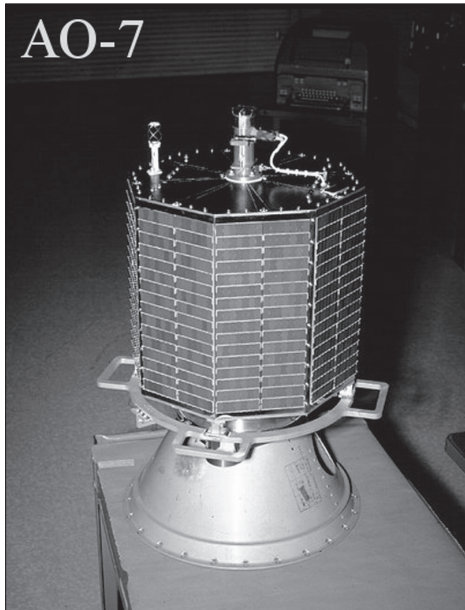


Figure 1: This is an image of AO-7 taken when construction was near final completion. It was photographed in its mounting fixture and shows the latent characteristics of the solar panels as flown. The basic shape is a cylindrical octagon. The image shows a circumstance where three out of the four quadrants would be illuminated by the sun if the viewer were the sun. One quadrant fully illuminated, the other two partially illuminated and with low illumination angles (Photo credit: Dick Daniels, W4PUJ).

electric currents captured in the 2009 telemetry were compared to the full radiation aged solar array and spacecraft attitude model. The telemetry minus model plots show evidence of differences with spin orientation. The difference may be caused by increased absorption or scattering of sunlight by yellowed, darkened cover-glass.

Introduction

AMateur SATellite (AMSAT), Orbiting Satellite Carrying Amateur Radio (OSCAR) 7 (AO-7) was one of two secondary spacecraft launched into orbit on 14 November 1974 from Vandenberg AFB on a Delta 2 (2310) booster along with the primary spacecraft ITOS-G (NOAA-4). Additional identifications for AO-7 are the international launch designation 1974-089B and the satellite orbit catalog number 7530. AO-7 ceased operating in 1981 after the battery system failed due to a short circuit [1]. Surprise! On Friday 21 June 2002, 28 years

powered only by the solar array when in sunlight. This is due to the fact that its NiCd battery has become an open circuit after initially shorting out in 1981. The open circuit state allows power to flow to the payloads, but only when the solar array is illuminated by the sun. The key to defining which transponder mode the satellite is in is whether or not the satellite is in or out of eclipse season. AO-7 has two amateur band allocation linear transponder communication payloads. The first transponder is a 2 m uplink and a 10 m downlink called mode A (new style mode code V/A). The second transponder is a 70 cm uplink and a 2 m downlink called mode B (new style mode code U/V). Mode C (U/V) is a low transmitter power mode automatically selected when low power states existed in the battery system but otherwise is the same as mode B. Mode D was also called "recharge mode" and only a telemetry beacon was

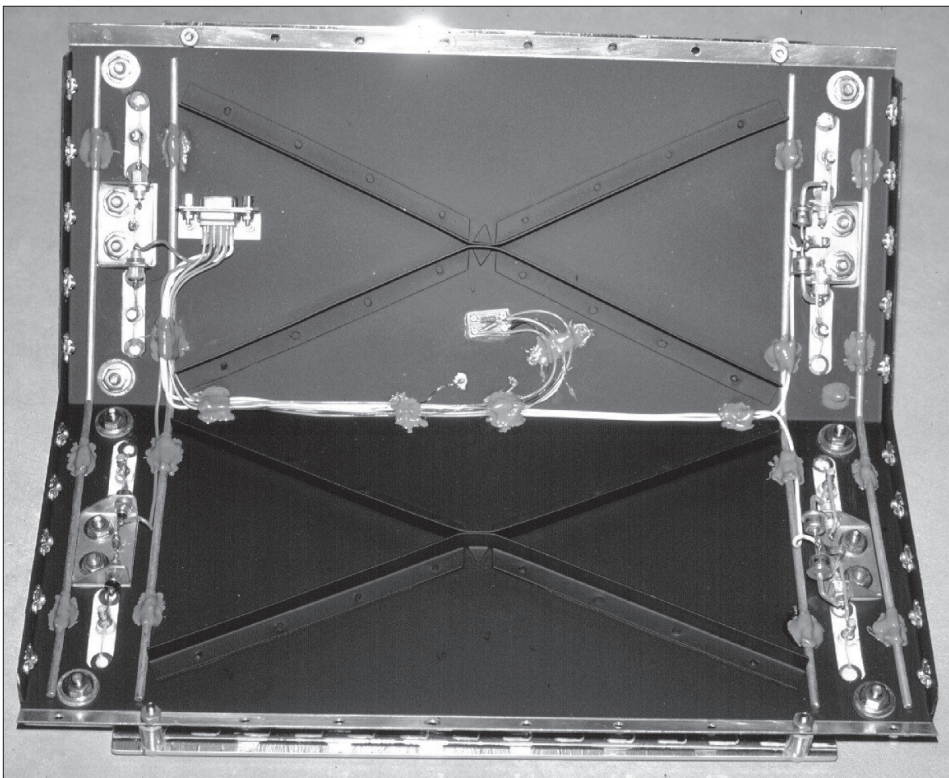


Figure 3: An image showing the latent characteristics of the backside (AO-7 interior) of a solar array "facet" showing the prominent beryllium heat-sink mounting plates, temperature sensors, Schottky diodes, wiring, connectors, mounting hardware, and the Allegheny Ludlum type 4750 Permalloy hysteresis rods. (Photo credit Dick Daniels – W4PUJ).

allowed to be in operation. The original design of AO-7 required the 435.1 MHz RTTY telemetry beacon to be commanded on by a ground station when in Mode A. This commanded mode is important because the spacecraft systems sample and report telemetry at useful Nyquist rates, one value every ten seconds on average. This rate of reporting of data in the telemetry allows spin rates to be determined from the solar array quadrant current time-series. When AO-7 is in full sunlight (no eclipses) the AO-7 solar array provides enough voltage and current to run the payloads continuously which allows the still functional 24 hour timer (counter-divider-based) circuit to switch between mode B (U/V) and mode A (V/A). However, when AO-7 is in eclipse season the payloads get reset each orbital revolution due

to the drop to zero power levels at sunset. When power is reapplied to the payloads at sunrise AO-7 consistently comes up in mode B. These behaviors are all features of the original design of the spacecraft [1], [3].

The OGO/AO-7 Solar Panels

The National Aeronautics and Space Administration's (NASA) Orbiting Geophysical Observatory (OGO) series of spacecraft (1 through 6) were launched over the period 1964 to 1969. The OGO solar cells and panels were designed, built, and tested by the prime contractor, TRW Systems Group, Space Technology Laboratories, Inc. Redondo Beach, California, to provide a solution satisfying the two major OGO orbit profiles [4], [5] and [6].

The two orbit profiles for the OGO series of spacecraft were eccentric (EOGO) and

polar (POGO) orbits. OGO solar arrays were designed to survive the harsh space environment related to travel through the Van Allen radiation belts that the EOGO type missions would require as well as the thermal stresses between eclipse and full sunlight.

The NASA OGO program provided sixteen spare, not selected for OGO flight, solar panel modules to the construction of AO-7. An OGO solar panel was made up of 112 gridded P-N junction Silicon (Si) cells, 7 cells wired in parallel and 16 cells wired in series. Each cell originally provided approximately 0.45 Volts (V). A loaded open circuit voltage of 7.2 V was produced at the panel output. A Schottky diode produced a voltage drop of about 0.45 V with gave an open circuit voltage (Voc) into the Battery Charge Regulator (BCR) of about 6.75 V at ambient temperature at the beginning of life (BoL). Another important BoL number was the voltage at the solar array maximum power point (Vmp) which was 5.38 V. Each individual cell has an effective area of approximately 1.9 cm² combined with the solar constant of 135.3 mW/cm² would provide 2.3 watts of power from each panel [7]. Parameters important to photovoltaic-based power generation in spacecraft are the voltage (V), the current (I), and power (P), $P = V * I$ sometimes called Watt's law. Two OGO panels make up an AO-7 facet. There are a total of eight facets on AO-7. Two AO-7 facets make up a quadrant (four quadrants total on AO-7), see Figures 1 and 2. A facet would provide peak ideal power of 4.6 watts per facet in full sunlight at launch BoL in 1974. After 35 years of radiation exposure the ideal wattage should be down to about 3.05 watts per facet (-33% BoL) and the Vmp about 4.55 V (-15% BoL). Solving Watt's law gives an ideal maximum current output of about 670 milliamps (mA) in 2009. After adjustment of the maximum current output for facet spin attitude and Beta

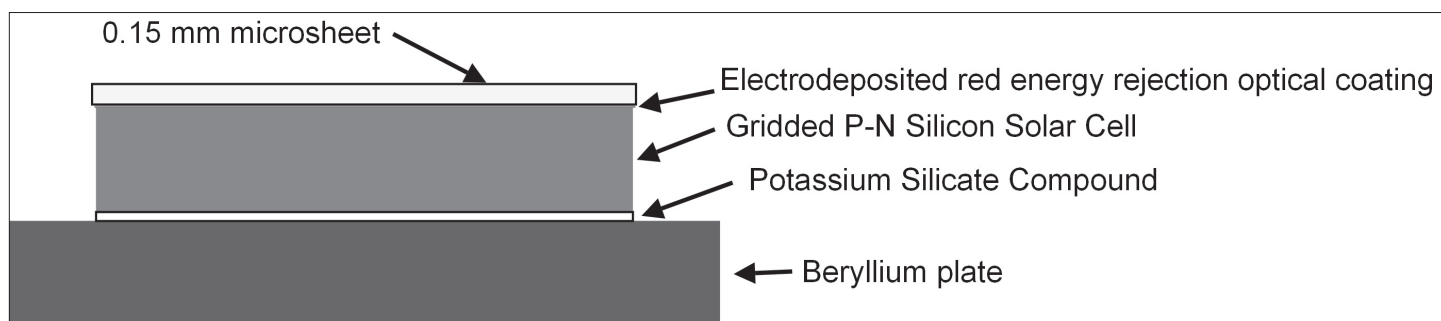


Figure 4: This shows a cross-section through an OGO/AO-7 solar cell. It is not clear from the literature if the electrodeposited red energy rejection filter on the solar cell cover-glass was placed on the outside (to space) surface or the interior surface. It is assumed and shown in the figure to be on the interior surface to protect it from surface erosion.

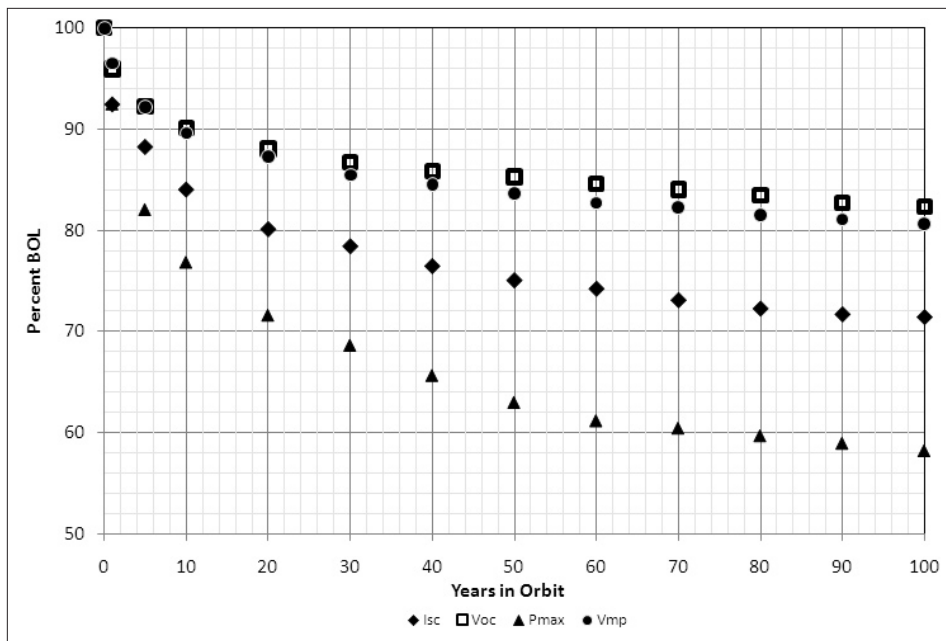


Figure 5: This is a plot of the radiation induced output reduction curves produced for AO-7's orbit accounting for the P-N silicon solar cell type, 0.15 mm cover-glass thickness, and related characteristics. The percentage of BoL values with time in orbit are shown for the short-circuit current (Isc), open-circuit voltage (Voc), maximum output power (Pmax), and maximum power output voltage (Vmp).

angle reductions a DC current of about 603 mA per facet should be output at maximum illumination circumstances during March 2009. The raw average DC current from each of the two facets which make up a quadrant is the only valid solar array parameter that is

captured and transmitted in telemetry [3].

The battery charge regulator (BCR) produced an output of 1.0A @ 14V from the raw solar array inputs. The 14 volt supply bus voltage then went to the batteries, to the 14V loads, and to power switching

regulators (redundant) that produced +28, +10 regulated, -6 regulated, and -10 volts for other spacecraft loads. A full Oscar 7 system block diagram is given in a February 1974 QST article [3], [8].

The solar cells were mounted on a substrate of beryllium (Be) plate which was selected by TRW to provide thermal mass to reduce the amplitude of heating and cooling and thus overall thermal stress on the cells and the electrical interconnections during thermal cycling between sunlight and eclipse. The main advantage in the selection of Be is it's coefficient of thermal expansion is similar to Si. Finally the Be plates were mounted to a light-weight aluminum framework which was attached to the main spacecraft frame, Figure 3.

The solar cells were covered by 0.15 mm (0.006 inches, 6 mils) thick micro-sheet cover-glass. Each cover-glass had an electrodeposited optical coating that was applied to provide red energy rejection to provide further thermal protection for the Si cells. The micro-sheet cover-glass provided limited radiation protection as well as limited protection from micro-meteoroid/space junk impact damage to the underlying Si photovoltaic material. The cover-glass was attached with an adhesive that had out-gassing issues during the OGO missions.

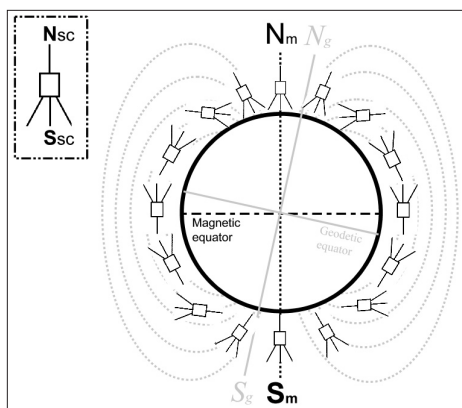


Figure 6: AO-7 is a magnetic field pitch attitude stabilized satellite. The diagram is for a viewpoint normal to the orbital plane. The figure shows the two-rotations per orbital revolution. The magnetic poles of AO-7 are shown in the upper-left inset box. The best way to understand and visualize the attitude of AO-7's attitude over an orbit is to remember that in magnetic fields opposite poles attract. AO-7 is essentially a bar magnet suspended in earth's magnetic field. When in the northern hemisphere the south pole of AO-7 (Ssc) points along the field lines towards the north magnetic field of the Earth (Nm). While in the opposite hemisphere AO-7's north pole (Nsc) points towards the south magnetic pole of the earth (Sm) along the local field lines.

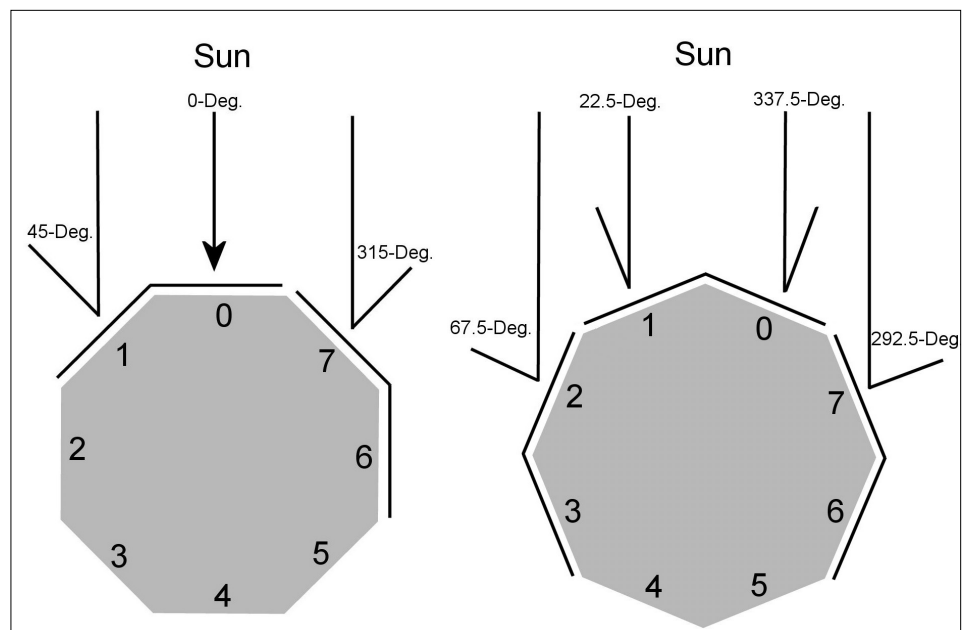


Figure 7: The shape of AO-7 as viewed from above or below is an 8-sided polygon. Only those AO-7 solar array quadrants that are illuminated by the Sun are shown floating above the surface for clarity. If the sun is up the page then the two basic solar illumination situations are shown. The left side diagram shows the illuminated quadrants when the sun would be normal to a facet, two quadrants (3 total facets) are illuminated. The right side diagram shows the illuminated quadrants with the sun normal to a quadrant vertex, three quadrants (four total facets) are illuminated. This right diagram is the maximum power output geometry.

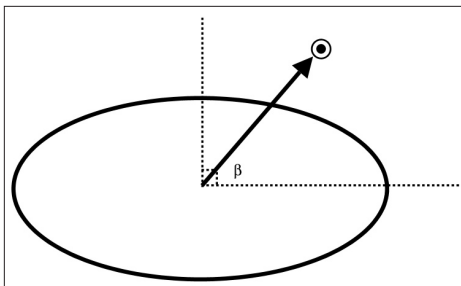


Figure 8: This figure shows a graphical description of the beta angle. It is the angle between the orbital plane and the directional vector to the sun and is one of the components that must be modeled for determination the output power of the solar array quadrants on AO-7.

Therefore, there was additional space qualification testing required by the launch primary spacecraft team (ITOS-G) for AO-7's panels, including cold finger testing in a vacuum chamber. This was done to confirm that AO-7 would pose no contamination threat to the primary spacecraft during pre-launch, launch, and early in orbit operations [9]. The rear surface of the solar cells were coated with a potassium silicate (K_4SiO_4) compound having a high infrared emissivity and a low visual and UV absorptivity and provided bonding and thermal coupling

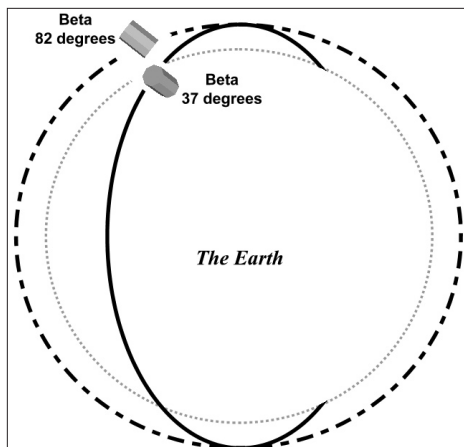


Figure 10: This is a plot that shows the maximum (82 degrees) and minimum (37 degrees) beta angle orbits as viewed from the Sun. The maximum and minimum illumination circumstances due the magnetic field pitch attitude stabilization with beta angle are shown as well. When the beta angle is near 82 degrees the solar panels present the same general aspect to the Sun and there is little beta angle variation during an orbit. See also Figure 6. However, as the beta angle decreases toward the minimum of 37 degrees the spacecraft attitude begins to become more significant as the sun angle with respect to the solar arrays decreases and produces less power. In addition, the illumination of the bottom and top of the AO-7 becomes larger. The top and bottom of the spacecraft contributes no power generation due to there being no solar cells on these surfaces.

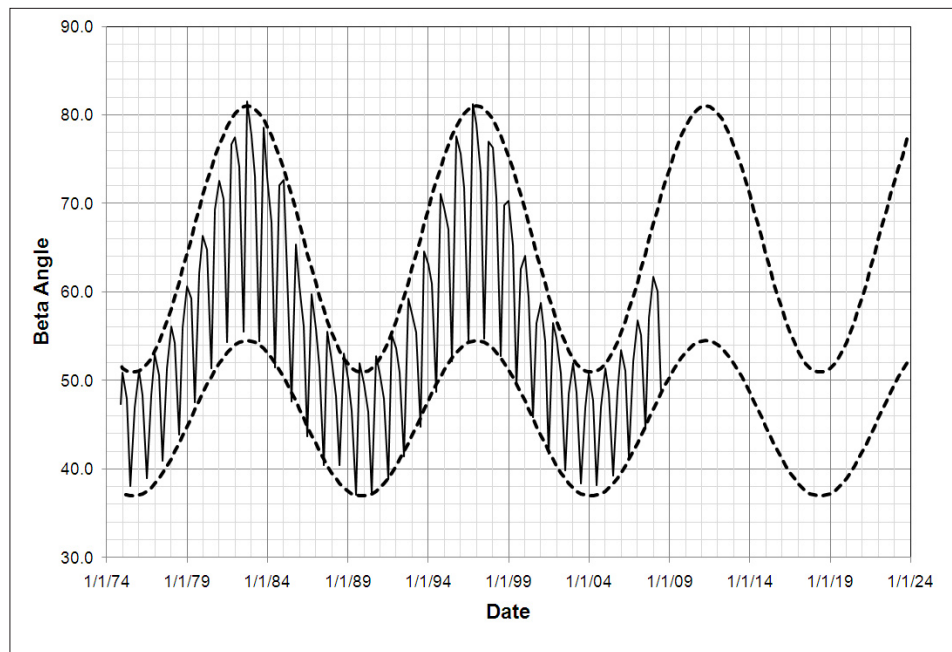


Figure 9: This is a time-series plot of beta angle for AO-7 from launch in November 1974 to 2009. Beta was sampled four times a year on 1 January, 1 April, 1 July and 1 October. Maximum beta angle was 81.5 degrees and the minimum was 37.1 degrees. Evident are the annual periodic as well as the slow 14 year orbital precession period signatures. An estimate of both beta angle maximum and minimum (the envelope curves) is propagated forward to the year 2024 (50 years since launch). The next low illumination circumstance (low power production from the solar array) occurs in 2018.

to the Be plate to keep the solar cell temperatures below 86° Celsius, Figure 4. Potassium silicate compounds are often used in adhesives and binders, in white thermal control paint, and other thermal coatings. In addition, potassium silicates exhibit radiation resistant properties [5], [10]. The fact that AO-7 is still working after 35 years (November 2009) in space is clearly a result of their basic overall ruggedness, the build margins, the build quality and required ground testing of all the new and OGO program contributed components.

Silicon Solar Array Aging In-Orbit

Once in orbit the photovoltaic power produced by Si solar cells will begin to decline generally in an exponential manner due to radiation exposure-based degradation of the Si atomic structure. The radiation induced decline in photovoltaic output power is dependent on the radiation environment fluence in the orbital regions the satellite passes through, the materials used in the photovoltaic cells, the thicknesses of the cells, any coatings, the cover-glass type and thickness, and etc. These radiation induced aging behaviors are well known and have been modeled thus allowing estimates of current, voltage, and power production to be made over time based on normalized 1 MeV electron fluence for the specific orbit [11]. The outer Van Allen radiation belt is made up

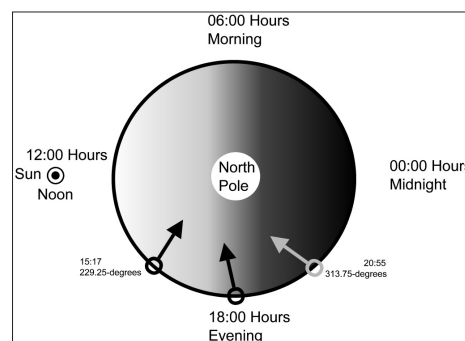


Figure 11: AO-7 is in an evening sun synchronous orbit. The figure shows the ascending equator crossing maximum, average and minimum times (angle) as viewed from over the earth's north-pole with the sun-earth line fixed to the left. The white zone in the polar region is the area where AO-7's sub-satellite point never reaches in its 101.5-degree retrograde orbit. The earth's equator is indicated by the outer circle. In this figure the earth rotation is counter-clockwise, right to left. The latest time over this interval was 20:55 (313.75 degrees) while minimum was 15:17 (229.25 degrees) over the period. The mean is 18:06 (271.5 degrees).

predominantly of electrons while the inner belt is dominated by protons [12]. AO-7's orbit has a nearly perfectly circular orbit with a mean height of about 1450 km which puts it at the lower edge of the inner Van Allen belt. Both proton and electron fluence at AO-7's orbital altitude have all been estimated and normalized to 1-MeV electron fluence so that by knowing the orbital inclination, mean

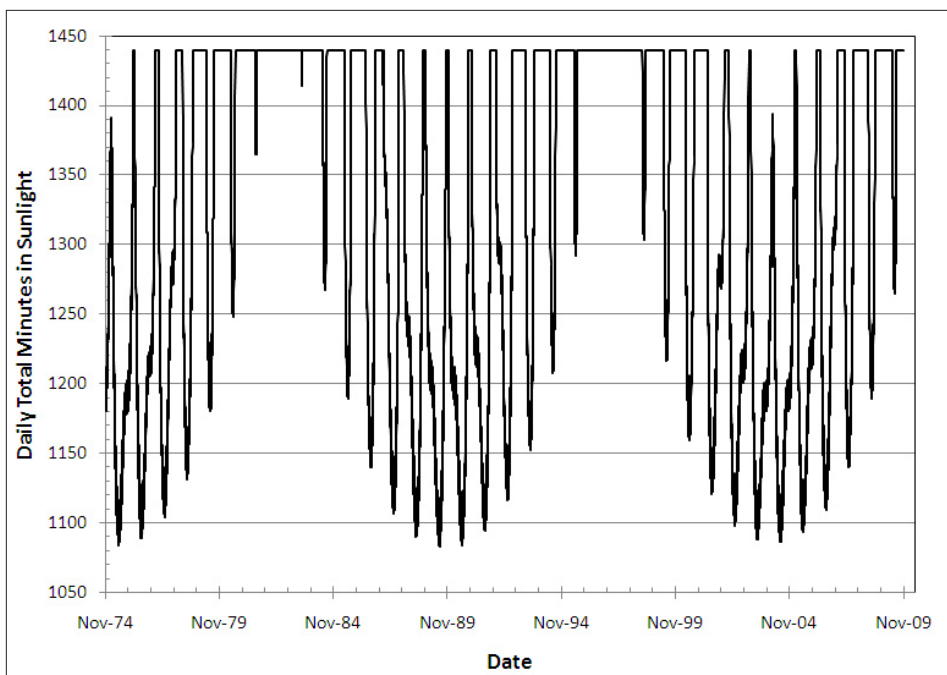


Figure 12: This plot shows the minutes of sunlight per day time series for AO-7. One day being comprised of 1440 minutes. The orbital precession period is about 14 years. Therefore, general illumination circumstances repeat with this period.

height, cover-glass thickness and coatings, and solar cell material (Si) a simple average estimate of the solar cell output loss over time may be created [11], see Figure 5 and Table 1. In 35 years the accumulated total equivalent 1-MeV fluence (e/cm²·cm - year) is 5.7×10^{15} .

AO-7's Pitch and Roll Attitude Models

AO-7's pitch attitude is controlled by

ALNICO-V permanent bar magnets which orient the spacecraft in Earth's magnetic field, Figure 6. The easiest way to remember AO-7's pitch attitude control is to visualize two magnets undergoing interaction and the fact that opposite magnetic poles attract. Therefore, AO-7 orients itself based on this rule pointing along the local magnetic field lines. Eight Allegheny Ludlum type 4750 Permalloy hysteresis rods, seen in Figure 3,

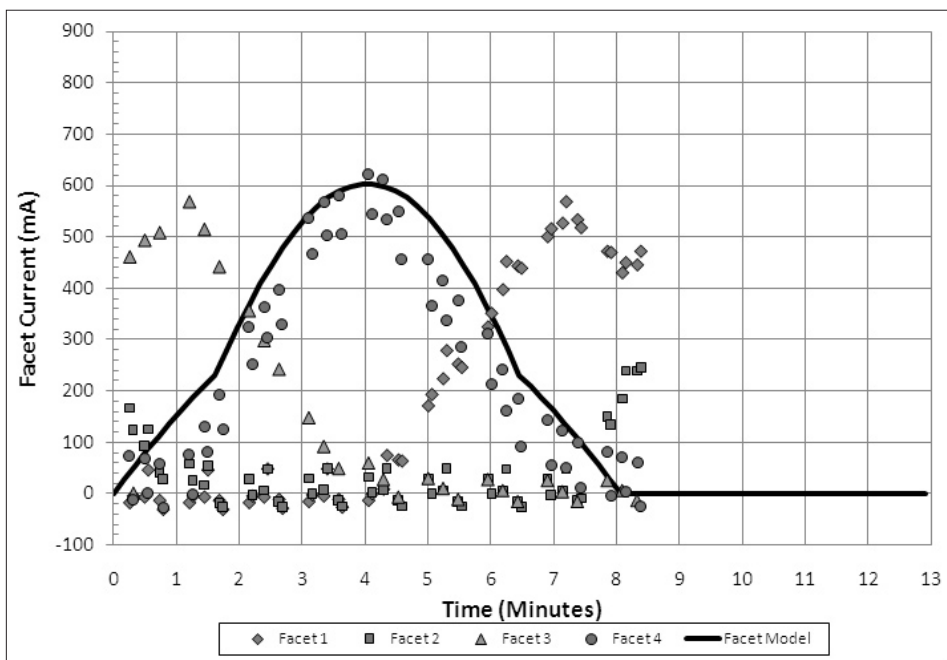


Figure 13: The 3 March 2009 RTTY solar array quadrant currents reported in the AO-7 telemetry stream. The solid curve is the expected current calculated from the models. The telemetry data were received by Alan, ZL2BX, in New Zealand. Clear spin modulation is seen. The spin period and rate were determined to be 12.9 minutes or 0.078 revolutions per minute.

provide dampening of precession, nutation and yaw motions as well as limiting roll spin rates in the radiometer spin stabilization method, Figure 7 [13]. Ultimately, AO-7 does a simple co-planar, in the orbital plane, flipping twice per orbit. Equation 1 is a simple pitch model that was developed for post AO-7 AMSAT microsats [14]. This model is also appropriate to use for AO-7.

$$b = 90 - \tan^{-1}[2 * \tan(g)] \quad (1)$$

where b is the local magnetic field dip angle and g is the Earth's magnetic field latitude, both in degrees.

In addition to the pitch attitude control AO-7 spins (rolls) due to the radiometer effect. The four "turnstile" antennas were painted black on one side and white on the other to produce the classic radiometry spin motion. Post launch (1974-1976) the AO-7 spin period stabilized near a period of about 14 minutes or 0.0714 revolutions per minute [15]. The spin rates observed in 1974 through 1976 were fully sufficient for smoothing of the temperature distribution over the spacecraft.

There are eight total facets on AO-7 each covered by two OGO panels. Each AO-7 facet is offset from an adjacent facet by 45 degrees. A simple spin orientation model is given in equation 2 which models the spin angle of each of the eight facets.

$$\text{Theta}(N) = \text{facet}(0)\text{Angle} + (45 * N) \quad (2)$$

$$\{(1 \leq N < 7) ; (0 \leq \text{Angle} < 360)\}$$

For example setting facet 0 to 22.5 degrees would place facets at 67.5, 112.5, 157.5, 202.5, 247.5, 292.5, and 337.5 degrees. The maximum quadrant solar array output is the right most case shown in Figure 7. Two facets make up a quadrant for a total of four quadrants on AO-7. Quadrant 1 being made up of facets 0 and 1, quadrant 2 made up of facet 2s and 3, quadrant 3 made up of facets 4 and 5, and finally quadrant 4 made up of facets 6 and 7. The four estimated radiation aged quadrant average DC current outputs are appropriate for comparison with the quadrant average electrical currents reported in the telemetry stream.

AO-7's Orbit and Beta Angle

Beta angle is defined as the angle between the Sun vector and the satellite orbital plane, see Figure 8. Beta angle was computed over the lifetime of AO-7 using spacetrack.org two-line orbit elements sampled every three months (four times a year) from 1974 to 2009. The general behavior of the variation of beta angle is shown in Figure

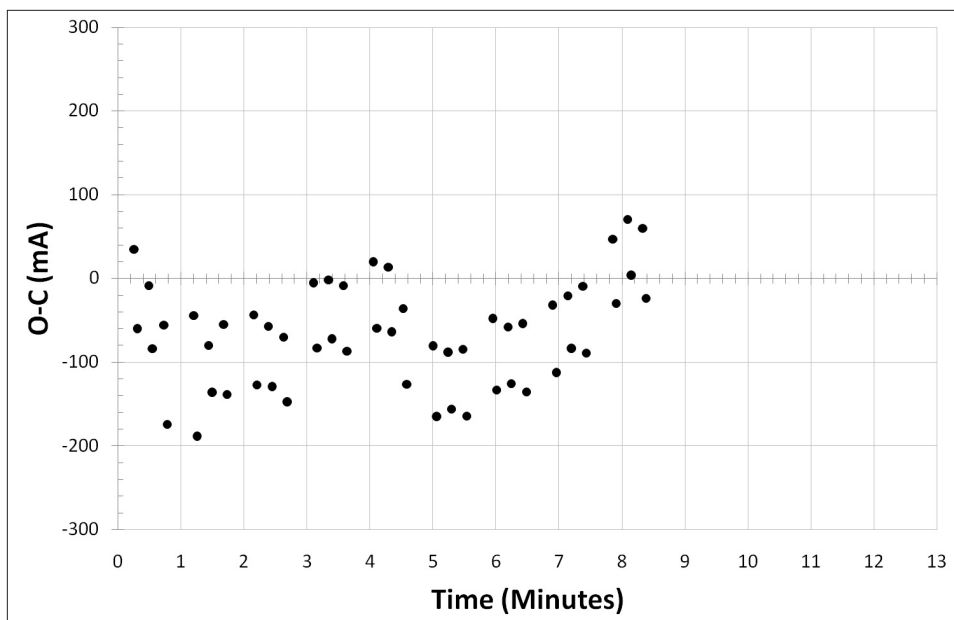


Figure 14: This plot shows the observed minus calculated (O-C) formed from ZL2BX's captured and decoded RTTY telemetry data for quadrant 4 minus the aged solar cell model combined current model. There is some periodic structure in the O-C diagram at low sun angle conditions.

9. The beta angle is the final parameter used to model the expected power output of the AO-7 photovoltaic system for comparison with telemetry. A simple sine curve was fit to the maximum and minimum beta angles and both upper and lower bounding curves that were extrapolated forward to 2024 (50 years on orbit) to allow visualization of the basic range of beta angle variation. The next lower illumination, low power production,

situation occurs around 2018.

The Full Solar Array Power Model

Combining the spacecraft pitch attitude, beta angle, spin orientation, and the solar array facet maximum output power value we form the general AO-7 solar array power output equation given in equation 3.

$$acp = \{\sum_{0-7}^N [fmp * \cos(\Theta(N))]\} * \sin(\beta) \quad (3)$$

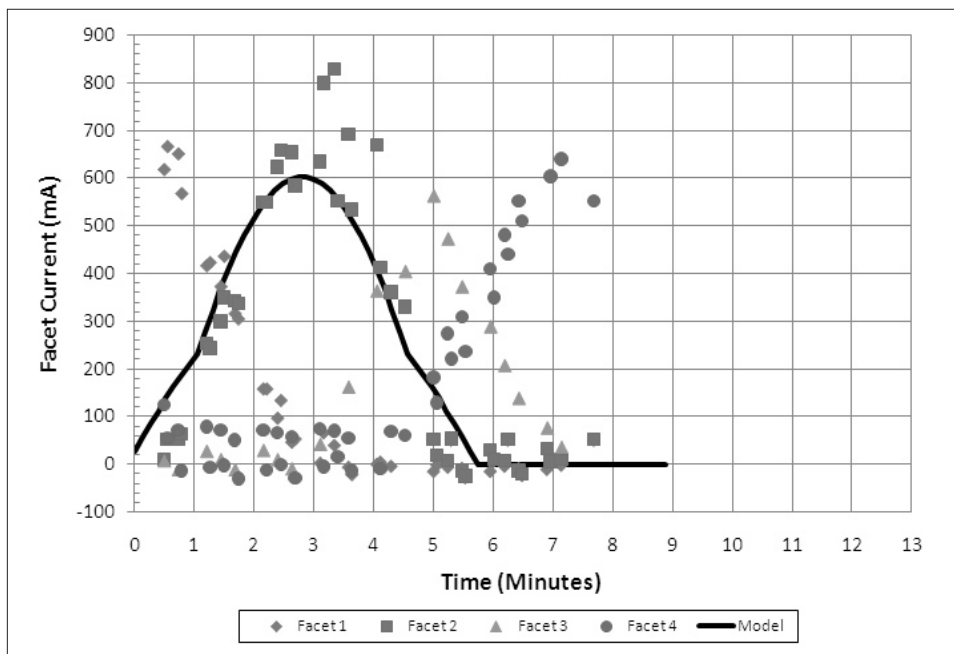


Figure 15: The 16 March 2009 RTTY solar array quadrant currents reported in the AO-7 telemetry stream. The solid curve is the expected current calculated from the models. The telemetry data were received by Mike, DK3WN, in Germany. Spin modulation is confirmed. The spin period and rate were determined to be 9.4 minutes or 0.106 revolutions per minute. The data plotted here shows some evidence of several incorrect RTTY character decodes.

where acp is the total AO-7 solar array output power in watts. The variable fmp is the maximum power produced by a solar array facet at BoL or as reduced due to radiation aging appropriate to total time in orbit. When the value of $\cos(\Theta(N))$ is positive the facet contribution is summed to give the total solar array output of AO-7. If $\cos(\Theta(N))$ is zero or negative it means there is no power output from that facet as it is in shadow. The final term accounts for the reduction in power realized from the Sun direction given by the beta angle. A model quadrant current output for comparison to the current telemetry data may be estimated by summing the facet groups [0,1], [2,3], [4,5], and [6,7] for quadrant 1, 2, 3, and 4 respectively.

AO-7 is in a Sun-synchronous orbit (inclination of 101.5 degrees and height of 1450-km) with the ascending equatorial longitude of the orbit varying between 313.75 degrees (20:55 solar time) and 229.25 degrees (15:17 solar time) with a period of about 14 years, see Figures 10 and 11. AO-7's beta angle varies between a maximum of 82 degrees and a minimum of 37 degrees. At beta angles near the maximum of 82 degrees the Sun is nearly normal to the spin axis and therefore the solar panels are fully illuminated by the Sun for the entire orbit. However, when the beta angle decreases towards the minimum of 37 degrees there are periods during the twice per orbit flip where the top and bottom of the satellite are illuminated which contribute no power. In addition, the satellite undergoes eclipses where the spacecraft power drops to zero. An example minimum power production situation is shown in Figure 10 for the case of beta angle of 37 degrees combined with the worst case pitch attitude which occurs four times per orbit.

The approximate total sun-time accumulated on AO-7 through 14 November 2009 is about 17.25 million minutes or 11979 days. Individual solar panels would have accumulated 50% of the given accumulated sun-time due to only $\frac{1}{2}$ of the satellite being illuminated at any one time. Over the next four or five years AO-7 will be experiencing less and less eclipse time and will be more often in the full-sunlight cycling of mode A/Mode B regulated by the 24 hour timer, Figure 12.

2009 High-Speed RTTY Telemetry

There were two telemetry systems implemented on AO-7; a Morse code (CW)



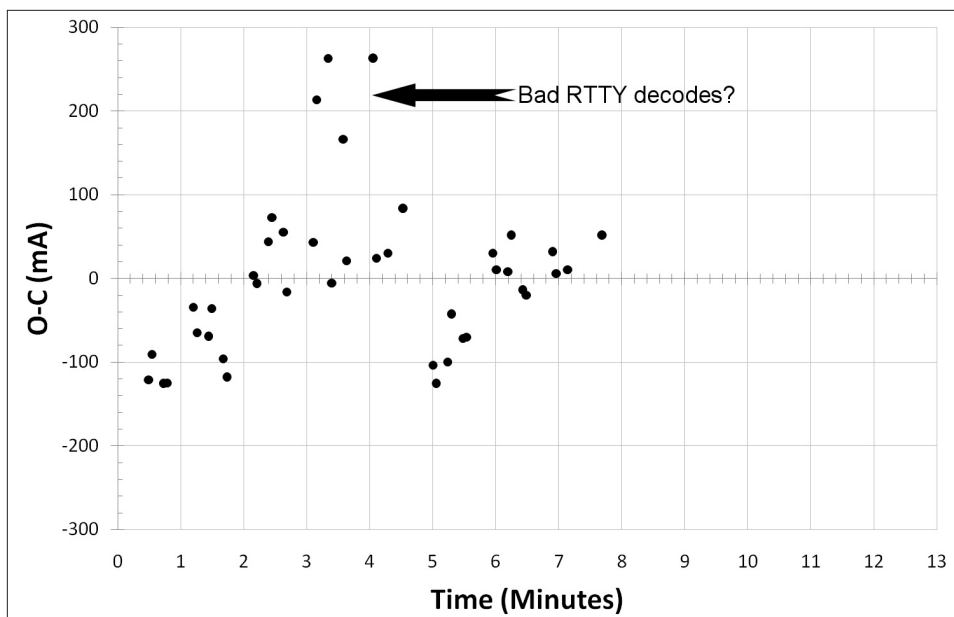


Figure 16: This plot shows the observed minus calculated (O-C) formed from DK3WN's captured and decoded RTTY telemetry data and the aged solar array quadrant current model. Four possible bad RTTY decodes are indicated. There is again significant structure in the facet 2's O-C diagram at low sun angles as was seen in ZL2BX's O-C diagram for facet 4, Figure 14.

and a RTTY system. Since recovery in 2002 AO-7 most often has sent low-rate Morse code telemetry or the telemetry beacons have been silent. Beginning in late February 2009 and continuing into March 2009 AO-7 was observed sending higher rate RTTY-based telemetry. This change in the satellites behavior was either due to commanding by one of the control stations or by some local spacecraft event that switched on the 435.1

MHz RTTY telemetry while in mode A. The mode A and 435.1 RTTY telemetry state was a commanded on only state so it is presumed an attempt was made to command her by a control station. It is not known by which station. A full AO-7 control logic diagram was published in 1974 February [3].

AO-7 RTTY telemetry is transmitted at 45 baud (~57 WPM) using an 85 Hz shift. This results in a real throughput of about 7.16

characters per second. A sentence of RTTY telemetry is made up of 60 characters. Each 60 character sentence is made up of 10 telemetry values (each are 6 characters long). The first character is a hyphen (-), the next two characters are the telemetry teletype (TT) channel ID, and the last three characters are the telemetry measurement in engineering units. There are a total of 8 sentences in a full telemetry set. It takes about 67 seconds to transmit the full telemetry frame of 480 characters. During a full frame of telemetry a total of six groups of solar array facet currents are transmitted. Each group is made up of four solar panel facet currents. TT channel IDs beginning with numbers 1, 6, 21, 26, 41, and 46 contain the average solar array quadrant currents, see Table 2. TT channel 34 was to contain the total combined array currents but the engineering value is always 000 and therefore is invalid. There are no other telemetry fields that report raw unregulated solar array outputs.

The RTTY telemetry linear conversion equation and 1974 coefficients were used to modify the received three digit solar array current engineering values and give calibrated average facet quadrant currents, equation 4.

$$FC = C1 - C2 * EV \quad 4)$$

FC is the AO-7 average quadrant current in mA, C1 and C2 are the appropriate quadrant ground determined constant and linear coefficients for conversion to real units, and EV is the three digit engineering value received in the telemetry stream [3]. Table 3 gives the coefficients for converting the engineering values to real units for each quadrant.

To provide better precision timing for determining spin periods an epoch time was set. The 0.0 second epoch was set to the receipt of the 1st character of a full 480 character telemetry frame. The subsequent times of receipt of each of the six sets of quadrant output current telemetry TT channels were found to occur as follows: TT -01 at 15.14 seconds, TT -06 at 18.52, TT -21 at 29.39 seconds, TT -26 at 32.75, TT -41 at 43.64 seconds and TT -46 at 47.02 seconds. These timings were applied to account for the non-equally spaced in time output of the quadrant current telemetry.

Four Amateur Radio operators collected telemetry of good quality to be usable for analysis during March 2009, see Table 4. Only telemetry collected over a sufficient

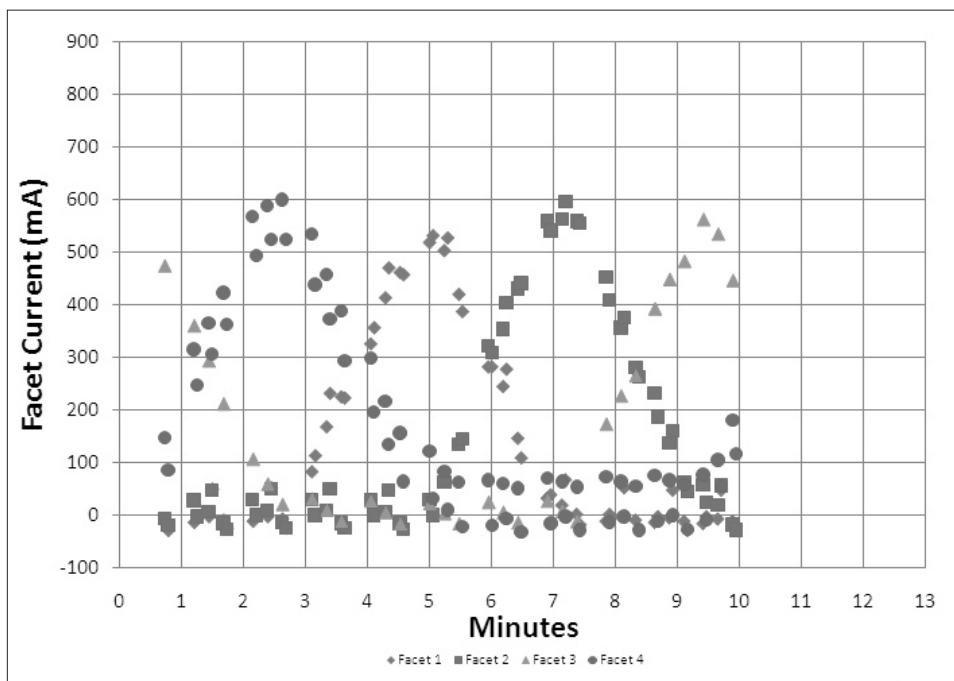


Figure 17: This is a plot of the facet DC current telemetry time-series data received by Alan, ZL2BX, during a near-zenith pass of AO-7 and shows the fastest determined spin period at 8.9-minutes. The data were obtained on 4 March 2009 starting at 19:45 UTC. A full spin period was covered. This spin period was the shortest observed.

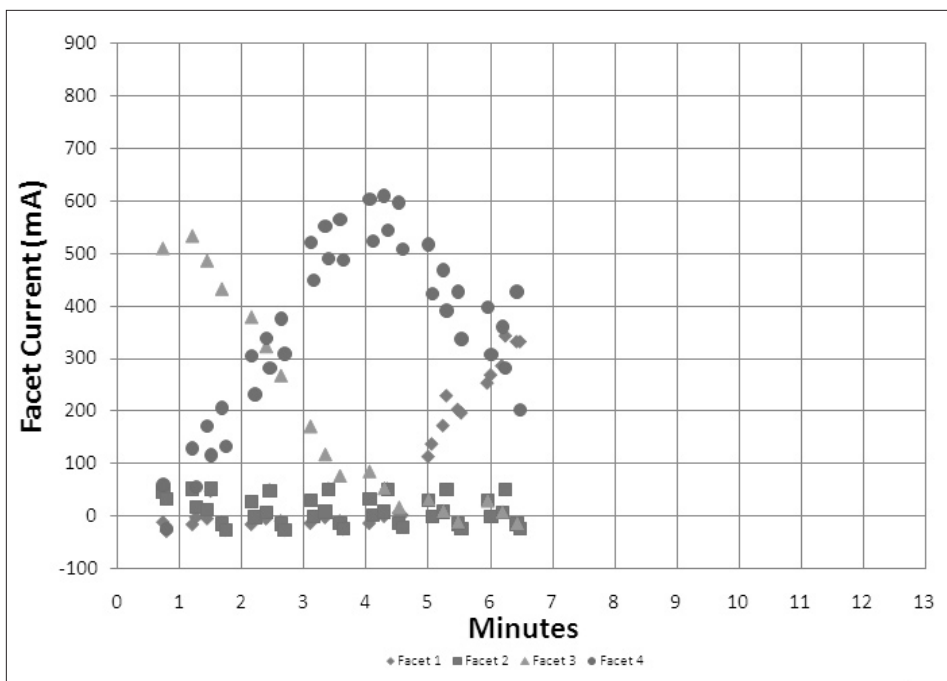


Figure 18: This is a plot of the quadrant DC current telemetry time-series data received by Alan, ZL2BX, during a low elevation eastern pass of AO-7. The data were obtained on 5 March 2009 starting at 05:54 UTC. The spin period is estimated to be 14.5 minutes and was the longest observed.

length of time (four to five minutes) and with consistent good RTTY character decoding was used in determination of observable parameters for AO-7. The parameters determined were the spin period and solar array current outputs with spin orientation. Two representative sets of data were selected for comparison with the solar array output and attitude model.

Alan, ZL2BX, (New Zealand) collected 76

sentences of RTTY telemetry on 3 March 2009 for a pass starting at 09:46 UTC and ending at 10:06 UTC [16]. Using this southern hemisphere collected data a 12.9 minute spin period, 0.078 revolutions per minute, or 27.9 degrees per minute spin rate was determined, see Figure 13. The spacecraft attitude and radiation degradation DC current output model for 35 years of radiation exposure is plotted for quadrant 4 for comparison. The

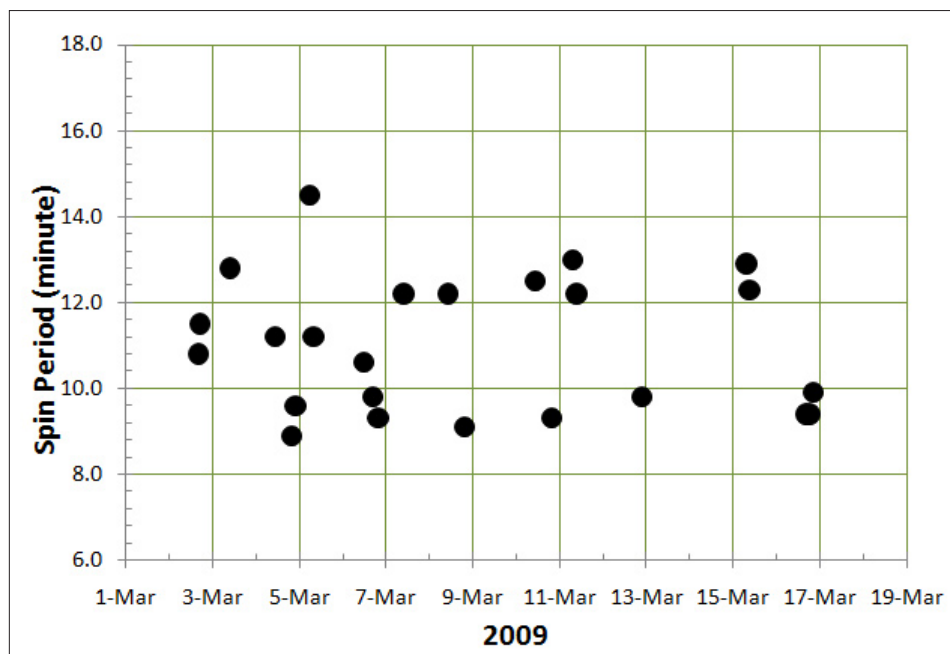


Figure 19: This is a plot of the time-series of the spin period for AO-7 during March 2009. The mean spin period was found to be 11.0 +/- 1.6 minutes. The slowest spin period was 14.5 minutes and the fastest was 8.9 minutes.

lower increase and decrease in solar array output, the “shoulders”, in the model curve, occurs when a quadrant has only one facet illuminated by the Sun and the other facet at a low angle of incidence thus contributing to the lower rate change in power output.

Observed minus calculated (O-C) values for quadrant 4 currents collected by ZL2BX on 3 March were generated by subtracting the observed telemetry values from the calculated and interpolated solar cell DC current aging model. There is some periodic structure evident but generally the fit is fairly good, see Figure 14.

Mike, DK3WN, (Germany) collected 58 sentences of data on 16 March 2009 beginning at 16:13 UTC [17]. DK3WN’s data provides an independent comparison from a northern hemisphere ground station and results in a 9.4 minute spin period, 0.106 revolutions per minute, or 38.3 degrees per minute rate, Figure 15. The radiation degradation current output model for 35 years of exposure is plotted for quadrant 2 for comparison.

O-C values for quadrant 2 currents as collected by DK3WN on March 16 again show some periodic structure. Four telemetry values near maximum current output of quadrant 2 are likely bad RTTY decodes, see Figure 16.

Alan, ZL2BX, observed a complete spin cycle of AO-7 during his 4 March 2009 19:45 UTC pass and the spin period was found to be 8.9-minutes, 0.112 revolutions per minute, or 40.4 degrees per minute rate, Figure 17. Approximately 10 hours later during the 5 March 2009 05:45 UTC pass Alan, ZL2BX, received RTTY telemetry during this low elevation pass and the spin period was determined to be just 14.5 minutes, Figure 18. This is an increase of about 63% in the spin period over the 10 hours between the two passes.

All of the spin periods are plotted in Figure 19. The mean spin period was found to be 11.0 +/- 1.6 minutes with peak-to-peak values ranging from 8.9 minutes to 14.5 minutes.

Discussion and Conclusions

Of the three components of Watt’s law ($P = V * I$) the only component fixed by measurement, obtained from telemetry, is the four quadrant currents (I). The average peak quadrant current from the 24 passes with good telemetry is 0.59 A. We now go through the basic process of obtaining an



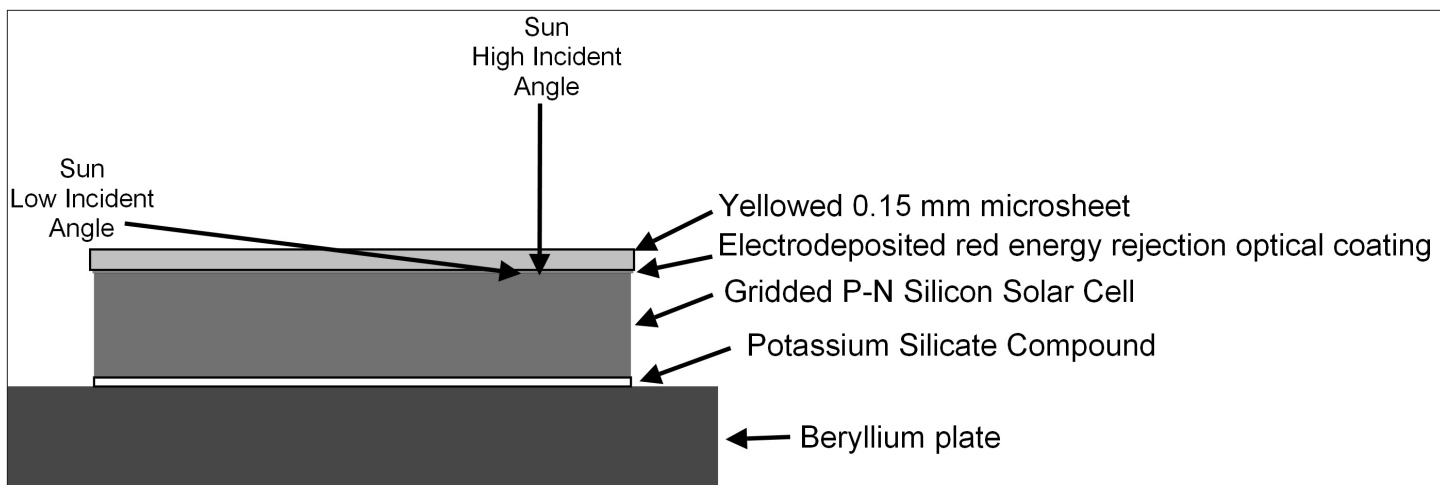


Figure 20: This cut away view of the solar panels shows the cover-glass as it might appear after 35 years of ultraviolet (UV) and particle radiation. The yellowing (cover glass darkened in the gray scale image) acts as a filter and absorbs and scatters light away from the silicon solar cells, especially at low sun angles. Compare this to Figure 4. This is the most likely explanation for the O-C curve structure shown in Figures 14 and 16.

estimate of a quadrant's power output at maximum power circumstances accounting for 35 years of radiation output reduction, spin attitude and beta angle. The maximum power geometry is shown on the right side of Figure 7. Set facet angles of 22.5 and 337.5 for the two facets making up a quadrant for that situation. Next obtain the +35 year radiation reduced maximum power estimate for a facet. We start with the maximum ideal

power at BoL which was 4.6 watts. After a reduction of 33%, see Figure 5, after 35 years of radiation exposure we obtain 3.05 watts maximum per facet in 2009. We next must adjust by the maximum power spin orientation angles. Quadrant power = 3.05 watts per facet * cos (22.5 or 337.5) since the geometry is symmetric. The result is 2.82 watts per facet. The total quadrant power, being made up of two facets, is

simply twice the facet power or 5.64 watts. Finally we must account for the beta angle by multiplying by sin (71.5) degrees during March 2009. The maximum quadrant power for the March 2009 telemetry on average would be 5.34 watts. Using this model estimate of the power output we may get an estimate of the quadrant voltage by solving the equation $V = P / I$. Solving we find a model estimate of the voltage from an AO-7 solar array quadrant of 4.78 volts during March 2009.

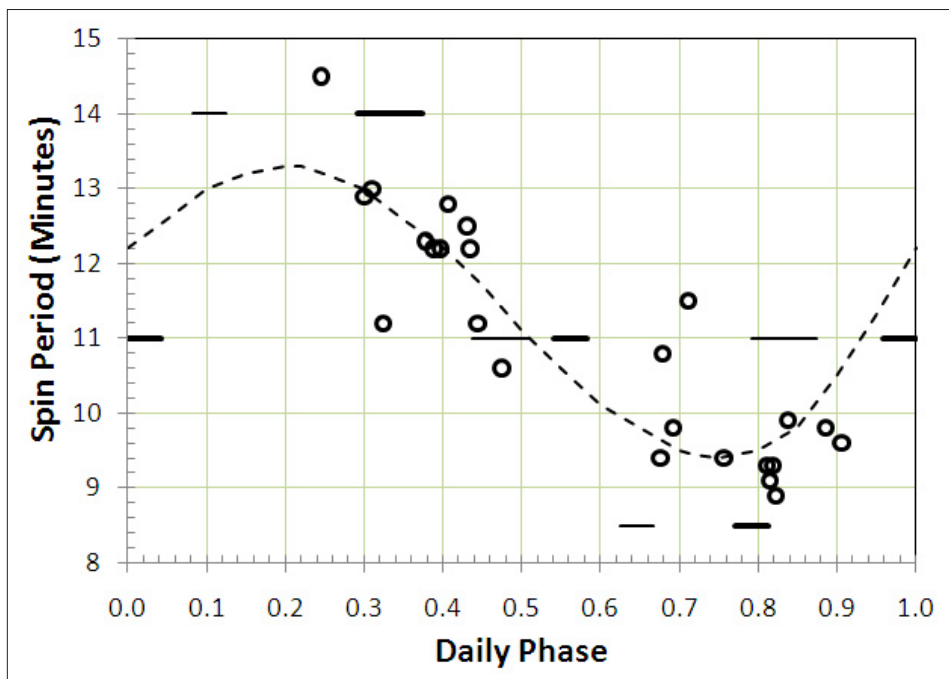


Figure 21: This is a one day phase plot of the AO-7 spin periods determined during March 2009 period. There is evidence of a diurnal periodic signal. The spin up/spin down of the spacecraft is likely caused by magnetic torques. Twice a day AO-7 travels along the field lines and at different times crossing normal to the field lines especially when near the poles. The plotted data indicates there is apparently induced spin torque changing the spin period of the satellite over a day. The horizontal lines indicate when AO-7 is crossing the field lines, thin lines indicate southern hemisphere times while thick lines represent northern hemisphere circumstances. The difference in times of occurrence between north and south hemispheres are caused by the fact that earth's magnetic poles are not coincident or symmetric with the geodetic poles.

Enough information is available to estimate the average agreement, between 1974 BoL and March 2009, via an independent path. Maximum BoL currents are reported for each of the four quadrants [3]. The average maximum BoL current for the four quadrants was 1460 mA or for an individual facet 730 mA. According to Figure 5 BoL Isc should be reduced by 23% to obtain the model estimate of facet current output in 2009. The resulting value for 2009 is 562 mA for a facet average current output. Adjusting by the sine of the beta angle of 71.5 during March 2009 we obtain a model average quadrant current of 533 mA. The average peak current reported in telemetry was 590 mA. So the agreement between telemetry and the model reduction in current is at the 11% level. Fortunately, the measured current is higher than the expected radiation aged model.

There was no correction made to the solar constant value due to the difference in the earth – sun distance (R) between 3 March 2009 (0.9913068 AU) and 16 March 2009 (0.9946934 AU). The difference in R being 0.0033866 AU between the two dates should produce only about 2 mA difference in

Table 1: AO-7's Radiation Induced Aging of the Solar Array Outputs						
Years in Orbit	Fluence (Isc)	Isc (%)	Fluence (Voc, Pmax & Vmp)	Voc (%)	Pmax (%)	Vmp (%)
0 (BoL)	0	100	0	100	100	100
1	1.0E10 ¹⁴	92	1.0E10 ¹⁴	96	93	97
5	5.0E10 ¹⁴	88	1.0E10 ¹⁴	92	82	92
10	1.0E10 ¹⁵	84	1.6E10 ¹⁵	90	77	90
20	2.0E10 ¹⁵	80	3.3E10 ¹⁵	88	72	87
30	3.0E10 ¹⁵	78	4.9E10 ¹⁵	87	69	85
40	4.0E10 ¹⁵	76	6.6E10 ¹⁵	86	66	85
50	5.0E10 ¹⁵	75	8.2E10 ¹⁵	85	63	84
60	6.0E10 ¹⁵	74	9.8E10 ¹⁴	85	61	83
70	7.0E10 ¹⁵	73	1.1E10 ¹⁶	84	60	82
80	8.0E10 ¹⁵	72	1.3E10 ¹⁶	83	60	82
90	9.0E10 ¹⁵	72	1.5E10 ¹⁶	83	59	81
100	1.0E10 ¹⁶	71	1.6E10 ¹⁶	82	58	81

Table 1: The normalized 1 MeV equivalent fluence radiation and percent degradation for silicon solar cells with a SiO coating on 0.15 mm (0.006 inches, 6 mil) cover-glass over 100 years of time.

Table 2: An AO-7 RTTY Telemetry Set										
Row	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10
1	-00567	-02547	-00567	-02547	-00567	-02547	-00567	-02547	-00567	-02547
2	-00567	-02547	-00567	-02547	-00567	-02547	-00567	-02547	-00567	-02547
3	-00366	-01918	-02878	-03644	-04873	-05010	-06912	-07893	-00000	-09909
4	-10000	-11768	-12336	-13714	-14603	-15937	-16417	-17396	-10000	-19148
5	-20484	-21913	-22897	-23669	-24848	-25010	-26889	-27880	-20000	-29871
6	-30000	-31000	-32000	-33503	-34000	-35222	-36232	-37261	-30000	-39257
7	-40501	-41916	-42913	-43703	-44819	-45010	-46924	-47917	-40000	-49851
8	-50000	-51765	-52329	-53009	-54000	-55000	-05600	-57000	-50000	-59849

Table 2: An actual full telemetry frame as received by Amateur Radio operator ZL2BX on 3 March 2009 beginning at his 09:46 UTC AOS. In one full telemetry frame there are 8 sentences made up of 10 telemetry teletype (TT) channels of data. There are a total of 6 current sub-sentences reported in each full frame of AO-7 telemetry, four facet currents per sub-sentence. The DC electrical currents are in row 3 TT frames -01 through -04, row 3 □

current output.

The AO-7 facet current O-C diagrams are shown in Figures 14 and 16. The O-C curves indicate lower than modeled current output at low sun angles. This means spin angles where only one facet of a quadrant is illuminated and at a low angle to the Sun. This case occurs when a single facet of a quadrant is illumination while spinning, see Figure 7. Since it appears in all the telemetry it would appear to be a real effect. The most likely possibility is that after 35 years the micro-sheet cover-glass has darkened somewhat and most obviously manifests itself as lower power output at low sun angle

attitude configurations due to increased absorption, scattering and reflection of sunlight by the cover-glass. See Figure 20.

The average AO-7 quadrant current outputs are about 11% higher than expected from the models. What is the future outlook for AO-7's power? A possible future of AO-7 is that it may have sufficient power available from the solar panels for quite some time perhaps optimistically until the year 2074, 100 years after launch, with a large, ill-defined uncertainty, of course.

By 2018, after 44 years in orbit, the radiation degradation will have reduced expected solar array output by Voc 15%, Vmp 16%,

Isc 24% and Pmax 36% of BoL levels. This situation may stress the transponder dynamic range and other reduced-power problems may become apparent at low beta angles by that time.

The spin period range of variation of 5.6 minutes, 8.9 to 14.5 minutes, in the space of ten hours is interesting. It is possibly a spin up, spin down phenomenon related to the spacecraft orbit which twice per day travels along the earth's magnetic field lines, no net spin force, while also twice per day the spacecraft crosses normal to the field lines near the magnetic poles causing a torque that once a day is added and then subtracted to



Table 3: Conversion coefficients for solar facet currents		
	C1	C2
Facet 1	1995	2.191
Facet 2	1968	2.175
Facet 3	1953	2.150
Facet 4	1954	2.150

Table 3: This table shows the solar facet conversion equations to convert from the transmitted engineering units to real units [3].

the average spin. The spin rates observed in 2009 are close to the stabilized spin rates reported post launch during the 1975 and 1976 period. The spin rates observed in 2009 continue to be nominal for maintaining sufficient distribution and smoothing of thermal heating on the satellite.

Figure 21 shows the 24 spin periods plotted as open circles on a daily phase plot. Zero hours UTC is 0.0 while twelve hours UTC is 0.5 phase. The thick lines correspond to the north magnetic pole and the thin lines correspond to the south magnetic pole cases. Lines at the y axis level of 14.0 minutes are when the orbit of AO-7 passes at a maximum distance from the magnetic pole and normal to the field lines. Lines at the y axis level of 11.0 are the approximate times when the orbit

is travelling along the field lines. Finally, lines at the y axis level of 8.5 are when the orbit passes nearly over the magnetic poles and are most strongly normal to the magnetic field lines of the earth. The north and south magnetic poles are not coincident or symmetric with the geodetic poles of the earth. This fact accounts for the offsets in time between the north and south poles shown in the plot. A hand drawn smooth line shows the estimate of the average magnetic torque affecting the spin period from both the north and south magnetic poles. The spin periods seem to indicate a daily spin up and spin down around the average induced by magnetic torques on AO-7.

There are many things that could cause a general failure in AO-7, however. Some are

a solar cell interconnect failure, a critical electronic component failure, significant damage from a micro-meteoroid or satellite debris impact, damage from an extreme solar storm event, the continued general environmental aging of components, or user extreme uplink powers causing failure of some critical aged component. If AO-7 avoids a discrete event death, then sometime in the future, due to generally reduced power output of the solar array as she continues to age will ultimately reduce the transponder and beacons to only burbles, groans and whimpers as a few satellite ground stations and a few terrestrial 70 cm signals still get into its receiver pass-band even after amateur satellite service users can no longer usefully make contacts through her. Finally, the AO-7 solar cells will no longer be able to produce enough useful power and she will go quiet silently orbiting the Earth for thousands of years, alone in the vacuum of space.

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Table 4: Amateur ground stations providing good telemetry		
Call	Country	Passes
ZL2BX	New Zealand	17
DK3WN	Germany	5
ST2NH	Sudan	1
ZS6BB	South Africa	1

Table 4: The four amateur ground stations that published usable telemetry to the Web are itemized. Their data was of good enough quality that the RTTY character decoding was unambiguous. These data were usable to obtain satellite spin periods and for comparison of the observed data with respect to the radiation degraded model solar facet current outputs.



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AMSAT is the North American distributor of **SatPC32**, a tracking program designed for ham satellite applications. For Windows 95, 98, NT, ME, 2000, XP, Vista, Windows 7.

Version 12.8a is compatible with Windows 7 and features enhanced support for tuning multiple radios.

Version 12.8a features:

- Select 2D/3D map with a single mouse click
- Select Political/Physical map with a single mouse click
- AOS voice announcement
- Countdown program displays next AOS of your favorite satellites
- Automatic Internet download of Keplerian elements.
- Graphical tracking on a world map with two selectable Zoom factors.
- One-click satellite switching using 12 "letter" buttons.
- Automatic rotor control support for: LVBTracker, Kansas City Tracker/Tuner, FODtrack, Uni_Trac, SatEL, Labjack U12/U3/Piggyback, W0LMD Mini/Junior/Senior Trackers, Yaesu GS-232, ARS from EA4TX, EGIS rotors, IF-100, RIF-PC, AMSAT-DL interface, WinRotor32, HalloRotor, and WiSP DDE clients.
- Doppler tuning with on-screen frequency displays. Radio models supported:
 - Yaesu FT-847, FT-736R, FT-817, FT-857, FT-897
 - ICOM IC-820H, IC-821H, IC-910H and other ICOM radios
 - Kenwood TS-790 and TS-2000
 - DDE client programs
- "Transparent" VFO-knob tuning in addition to keyboard and mouse tuning.
- "Virtual" VFO tracking for half-duplex transceivers FT-817, FT-857, FT-897, IC-706 and IC-7000.
- Includes a special version for ISS split-frequency operation.
- Controls subaudible tone on FT-847, FT-736R, FT-817/857/897, TS790A and IC-910H.
- Includes a non-graphical version and programs that output lists to the screen, printer, or a file.
- Interfaces with WiSP, with user-defined satellite switching priority.
- Includes a separate program for tracking the Sun and Moon.

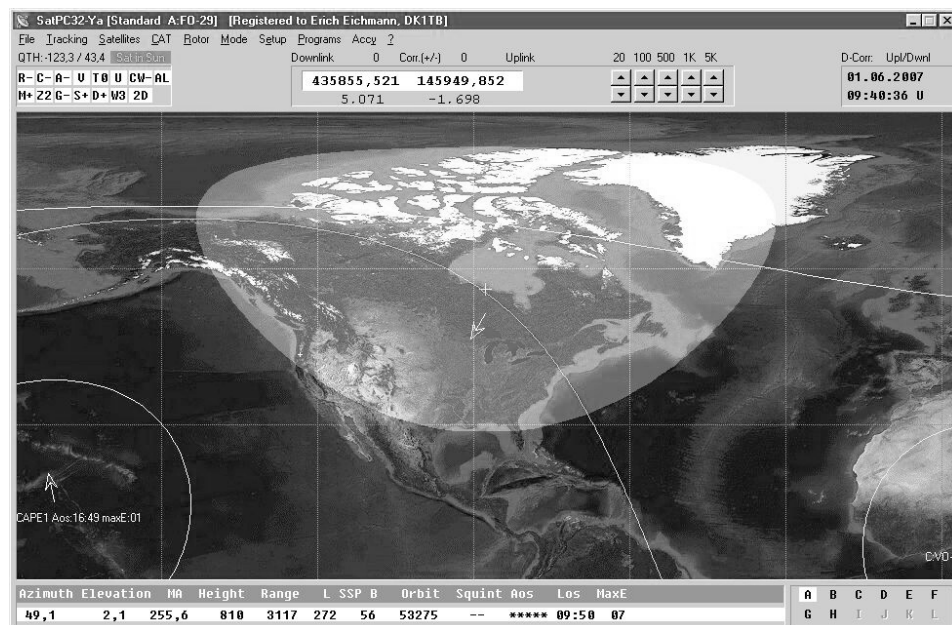
Price is \$45 for AMSAT members, \$50 for non-members, on CD-ROM.

A demo version may be downloaded from <http://www.dk1tb.de/indexeng.htm>

A registration password for the demo version is \$40 (members), \$45 (non-members).

Order by calling 1-888-322-6728.

The author DK1TB donated SatPC32 to AMSAT. All proceeds support AMSAT.



Thoughts on the Magic of AO-7

by Tim Lilley, N3TL, n3tl@amsat.org

“Longest-lived satellite in history.”

Those five words describe AO-7 on a Web page I visited recently. While not entirely accurate, they're close. AO-7 turned 35 on 15 November, 2009. According to the AO-7 log page on the Web (www.planetemily.com/ao-7), the satellite has completed more than 160,000 orbits. Impressive as it is, that number alone doesn't provide nearly the appropriate historic perspective on what I believe to be the flagship of the Amateur Radio satellite fleet.

Flagship? Indeed.

AO-7 handles a fraction of the usage that AO-51 enjoys (or, maybe, suffers through – depending on your perspective) on any given orbit. I don't believe popularity is the best measure of status – probably because I'm now much closer to retirement than high school graduation. Longevity is important, and AO-7 certainly owns that. Ease of operation counts too, and AO-7 certainly has proved easy to operate – even when using a station like mine.

From here, however, there is an intangible – something I feel inside every time I hear myself on the downlink. In an email to me, Leroy Stenzel, W5VG, described that intangible perfectly. “My first experience on AO-7 Mode A was in 1975,” he said. “It

was magic then. It is still magic!”

I turned 18 the month that AO-7 made the cover of *QST* magazine – April 1974. I still had a few weeks of high school left, and Amateur Radio remained an alluring prospect, as it had for many years. Back then however, the concept of learning Morse code thoroughly intimidated me, and I had to learn code to get a ham license back then.

Seven months after the *QST* cover gig, on 15 November 1974, a Delta 2310 rocket blasted off from Vandenberg Air Force Base, California, carrying a 28.8 kg (63.5 lbs) satellite that is 36 cm x 42.4 cm (14.2 in. x 16.7 in.). AO-7 arrived in a polar orbit with a perigee of 1,459 km (894.77 miles) and an apogee of 1,459 km (906.58 miles). Taking those orbital figures into account when doing the math, AO-7 has traveled roughly 49,042.86 km (30,473.2 miles) on each orbit.

On the evening of 24 November 2009, when W5VG and I had a CW QSO on AO-7 in Mode A, the satellite was in its 160,299th orbit according to the AO-7 log Web page. At the end of that lap around the Earth, AO-7 had covered 7.862 trillion km (4.885 trillion miles) since reaching orbit.

That's 0.831 Light Year!

More perspective:

- AO-7 has orbited through portions of seven U.S. presidencies (Gerald Ford, Jimmy Carter, Ronald Reagan, George H.W. Bush, Bill Clinton, George W. Bush and Barack Obama).
- The number 1 song on the *Billboard Magazine* chart on 15 November 1974 was *You Ain't Seen Nothing Yet*, by Bachman-Turner Overdrive. Is that prophetic?!
- Gasoline was under \$1 a gallon in the U.S. - if you could find it. Who else remembers the oil crisis of the early 1970s?
- Actor Leonardo DiCaprio was 4 days old when AO-7 reached orbit.
- The first bar code reader appeared in 1974. Can you guess what product carried the first bar code for it to read? Answer at the end of this essay.

AO-7 *isn't* older than something else that's still around today and working hard – the Post-It Note. Arthur Fry invented it in 1974.

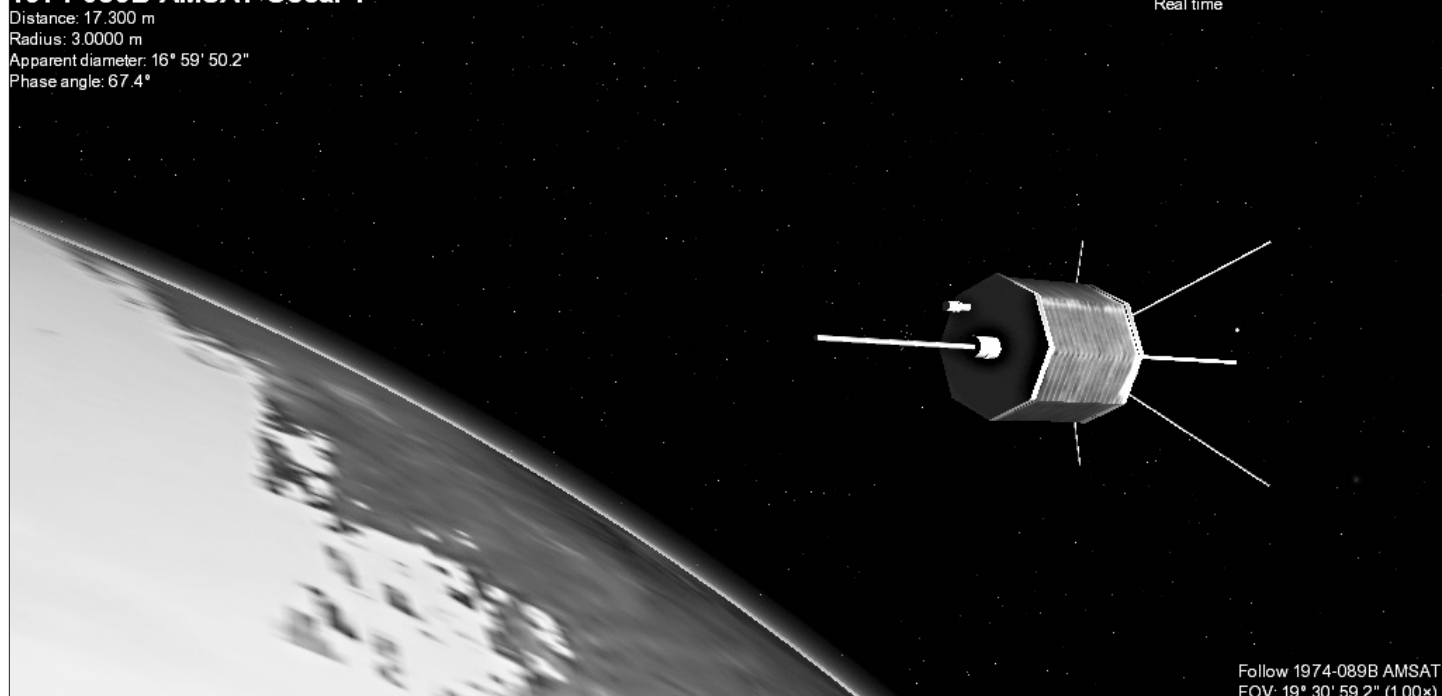
There weren't satellite-tracking software packages back then – *or* the Internet as we know it.

I remember how excited and proud I was to build my first CW interface for a computer

1974-089B AMSAT Oscar 7

Distance: 17,300 m
Radius: 3,0000 m
Apparent diameter: 16° 59' 50.2"
Phase angle: 67.4°

2009 Nov 25 21:06:50 UTC
Real time



Follow 1974-089B AMSAT
FOV: 19° 30' 59.2" (1.00x)

This is a screen shot of the Celestia planetarium program with AO-7 in orbit above Antarctica.



—specifically, the Commodore 64. My watch today has more memory! I also recall my thrill at editing the basic program published with the article about the interface so I could use the keyboard to run the Kansas CW Traffic Net. Um ... that was almost 10 years *after* AO-7 reached orbit. I didn't get my ham license until 1983. I never tried working satellites back then because I didn't have the money for all the radios and antennas I would have needed.

As a result, I'm a very late arrival to the world of amateur-satellite radio. I wasn't on the air to work AO-8, AO-13, AO-40 ... the satellites so many so fondly remember working. I'm grateful to have discovered the satellites while AO-7 is in its second life because I believe I have an idea of what it was like when the satellite was in its infancy. It had to be magic, as W5VG said, and it still is.

That magic is the second reason I'm writing this piece, which is about as technical as my satellite station is sophisticated. The first is that I want to help those like me — relative youngsters to the satellites — to understand how important AO-7 is to modern Amateur Radio history. The third reason is my hope that some of you will take the first two reasons to heart and try working AO-7.

Mode A uses a 2 m uplink and a 10 m downlink. Mode B uses a 70 cm uplink and a 2 m downlink. AO-7's is a linear transponder. It has a passband capable of supporting multiple contacts in CW and SSB at the same time during passes that can last more than 20 minutes.

What do you need to work AO-7? For Mode A — a 2 m all-mode transmitter and a 10 m all-mode receiver. For Mode B — a 70 cm all-mode transmitter and a 2 m all-mode receiver.

Doppler is a concern when working AO-7, especially in Mode B, but it's not so bad that you can't make multiple contacts on a pass while manually tuning for Doppler. I do it all the time. In fact, if you want to try some AO-7 contacts using manual Doppler tuning, the following starting points will get you pretty close.

Mode A — Set your downlink to 29.450 MHz and your uplink to 145.899.3 MHz.

Mode B — Set your downlink to 145.950 MHz and your uplink to 432.149 MHz.

At AOS, you should be able to find yourself in the downlink pretty quickly using these

numbers. If you don't, just remember that you'll be tuning UP on the downlink side from your starting point, as the pass unfolds, to keep your downlink at the same frequency. Tune around a little, and you should find and hear yourself fairly quickly.

Many thanks to Rick Tillman, WA4NVM, for the great help he provided in getting me up to speed with manual Doppler tuning when I first started working the linear satellites.

The Mode A transmitter had a 1 watt output when the satellite reached orbit. The Mode B transmitter had an 8 watt output back then. It's interesting to note that there also was a lower-power (2 watt) option for the UHF/VHF transponder that represented AO-7 Mode C. Mode C used the same passband (the same uplink and downlink frequencies) just at QRP power levels.

AO-7 went silent due to battery failure two years before I passed my Novice test. It stopped transmitting in November 1981. Pat Gowan, G3IOR, was tuning around the 432 MHz portion of the 70 cm band on 21 June 2002, when he copied what he ultimately determined was the AO-7 70 cm beacon. Visit the AO-7 log and resource Web site (www.planetemily.com/ao-7) to read the complete history of the satellite, including details from AO-7 Project Manager Jan King, W3GEY, on what he believes brought the satellite back to life.

I could include that information here, but this is about the magic of AO-7, not its science. The magic involves working Europe, Africa and Alaska from EM84. It involves using a straight key and an end-fed longwire to work a 35-year-old satellite and have a QSO with another operator sending CW with a straight key. W5VG and I did that during our Mode A contact.

Many satellite newcomers started out like I did — with a dual-band HT and a handheld Arrow antenna. I used dual-band, FM only HT as a transmitter to send AFSK CW over AO-7 — and over VO-52 and FO-29 before the latter went down. I intend to write a more-detailed article for the *Journal* in 2010 about “the little satellite station that can.”

I had a QSO with Steve, N3TE, in Maryland, that included hellos, signal reports and 73s from one station to the other. Fortunately, Glenn, AA5PK, was on that pass in west Texas and sent me an MP3 recording of the contact. I used a Yaesu VX-3R HT at 1.5 watts and a Yaesu VR-500 handheld all-

mode receiver. I connected a straight key to the mic input on the VX-3R to send AFSK CW. My signal had some chirp, but it was readable. A Diamond MX-72H duplexer enabled me to connect both radios to the Elk dual-band log periodic antenna I use these days.

I'm not suggesting that we all go out and work AO-7 by sending CW through a dual-band HT. I relate the story simply to encourage those who haven't tried the linear satellites — and especially AO-7 — to do so.

As noted at the start of this essay, at least one Web page calls AO-7 the “longest-lived satellite in history.” While the satellite is working today, there *was* that 21-year “nap” along the way. Last July, the *Scientific American* magazine Web site published a list of 10 “space aged satellites” still in orbit, and AO-7 is among them.

You'll find that longest-lived reference on a Web site called “The Celestia Motherlode.” If, like me, you enjoy all kinds of things related to space, Celestia is a freeware, open-source planetarium program you ought to check out. You can find the main program at <http://www.shatters.net/celestia/>. The “Motherlode” site is linked to the Celestia site, or you can find it at <http://www.celestiamotherlode.net/>

The Motherlode site is home to an amazing array of add-ons developed by Celestia users, and AO-7 is among them. When you visit the site, click on satellites, then on the submenu earth orbit. AO-7 is at the top of the list.

Using Celestia to get a look at AO-7 orbiting the Earth is wonderful, but it's not as good as hearing someone call N3TL in CW on the satellite. Piraja, PS8RF, did that a few minutes ago (as I type this) in Mode B. Brazil on AO-7 in CW. That definitely *is* magic. You should try it sometime.

Oh — as promised — the first bar code appeared on a pack of Wrigley's chewing gum. ☺





evaluation of critical design concerns and outstanding issues, and took place 15-16 Feb. Participants included team members from each of the functional areas plus individuals from NASA Johnson Spaceflight Center (JSC) and Goddard Space Flight Center (GSFC). Given the need for NASA safety certification that is required for ARISSat-1, having NASA personnel who have participated in other ARISS-sponsored activities is critical towards achieving our goal of placing ARISSat-1 in space in 2010.

The review was an excellent opportunity to highlight the accomplishments to date and reinforce those items that are areas of concern. Among those areas that have been completed and/or expected to be completed in the near term:

1. The Software Defined Transponder (SDX) is up and running with no issues identified. The SDX itself and the RF transceiver prototype is working along with the safety switch box.
2. The mechanical design is excellent and the space frame parts are being fabricated. We expect to build four units (two for the US and two for Russia, with one of the Russian units to be deployed to the ISS). The space frames are being constructed in Orlando and spacecraft integration will take place there as well.
3. The video cameras and associated electronics are functional.
4. The educational components are on track. This includes both the various audio recordings by students to be played on a downlink channel as well as the student experiment (the Kursk experiment to measure the vacuum of space) that is built in Russia.

However, AMSAT is at a critical point with ARISSat-1. As I write this column in late February, we know that AMSAT will not be able to deliver to RSC-Energia in April as originally planned. Our challenges are several:

1. Continued software development is needed for the Internal Housekeeping Unit (IHU) and Power Supply Unit (PSU). The IHU software work areas include telemetry, Kursk experiment operation, power management, TV camera operation and ground control operation. PSU software development is not complete especially telemetry data

collection. A problem was found with the Maximum Power Point Trackers (MPPT) that convert power from the solar panels to output capable of charging the Russian-provided silver zinc battery that requires hardware and software re-work.

2. Thermal analysis has shown that the spacecraft will run in a very cold condition, as low as -40C for some components. Because of this, some of the circuitry will require re-design and re-work to meet the new temperature environment. The Russian silver zinc battery's ability to operate in these cold temperatures was questioned at the review, but has since been determined that the battery will operate in this environment. The thermal issues are due to the shift to the new spacecraft design rather than use a surplus Orlan spacesuit.
3. There were safety and testing issues uncovered that require a new interconnect board design. Redesign of the Interconnect Board (ICB) will permit software upgrades to the IHU and PSU following integration into the spacecraft. Given the recent recognition of the need for parallel development of the spacecraft to incorporate software upgrades once the spacecraft is assembled and environmental testing is certified (which means not being able to disassemble the spacecraft to reload software into the various Microchip devices), it is critical that provision be made to allow physical connection to permit these software changes to be made as needed.
4. A formal NASA safety review conducted by personnel at JSC must be scheduled and documentation submitted 45 days prior to the actual review. Currently, payloads must be approved through this process prior to upload to the ISS. Documentation requirements are extensive and while most of the document package is completed, several items were identified during the Orlando meeting that require modification of our documentation. This additional documentation effort adds to the overloaded workload of key individuals.
5. The need for thorough testing following completion of the satellite. This includes both functional testing/checkout as

well as environmental testing (Thermal/Vacuum Testing) at GSFC prior to delivery to RSC-Energia.

6. Whether a later delivery schedule can be developed that will be acceptable to RSC-Energia given what needs to be rearranged by RSC-Energia to permit later delivery. These negotiations are ongoing.

ARISSat-1 offers significant potential for AMSAT both in terms of technology incorporated into the spacecraft (such as the SDX) as well as the desire to place a spacecraft in orbit that offers both educational outreach (such as the experiment developed by Kursk State Technical University) and operational opportunities for Amateur Radio operators around the world. Given the complexity of this spacecraft and the technical challenges noted above, there are currently serious concerns whether AMSAT will be able to deliver a reliable spacecraft by summer 2010 or if RSC-Energia will accept a later delivery.

What ARISSat-1 has also demonstrated is the need to rigorously define the development process and to spend considerable time working on specifications and documentation prior to satellite build. Given that this is an all-volunteer effort that is totally dependent upon certain individuals who hold day jobs and have other responsibilities; it is very difficult to stay on schedule if the time isn't spent first on satellite specifications. As I write this, the critical path is dependent upon two individuals (both non-AMSAT members, one of whom is not a ham) who are developing critical software as we've lost a key individual due to day job priorities. Whether these key individuals can complete the software development in time to permit subsequent testing/certification prior to the drop dead shipment date remains to be seen.

Impact on Other Engineering Projects

AMSAT announced at the 2009 AMSAT Symposium that we would build a CubeSat that will provide some of the services that are currently offered by AO-51. Our original intent was to start this project in early 2010 based upon the presumption that ARISSat-1 would be completed in late 2009. Subsequent to the Symposium, the AMSAT Board of Directors decided to name our CubeSat project Fox, reflecting the next alpha designation of an AMSAT satellite



project as AO-51 was called Echo when it was under development.

Given the continuing development of ARISSat-1 and the focus of our engineering team on this critical project, we have not started major development work of Fox. However, Bill Ress, N6GHZ, has started initial development work on the RF system based on preliminary specifications developed by Tony Monteiro, AA2TX. Meanwhile, fund raising efforts for Fox will continue under the expectation that once ARISSat-1 is completed our full attention will turn to Fox. As the ARISSat-1 project continues, we are noting lessons learned from ARISSat-1 that we expect to apply to Fox, particularly with regard to project management, including project definition and scope. Our expectation is that Fox will be an opportunity to change the culture/expectations of how satellite projects will be managed and that a CubeSat is a good opportunity to redefine how such projects are managed given the relative small size of the project versus our prior satellite projects.

Other Items

Dr. David Toth, VE3GYQ (SK): AMSAT has learned that Dave passed away on 26 Feb 10 following a long illness. He last served as President Emeritus of TAPR and attended the 2009 Joint AMSAT-TAPR Dinner at Dayton. David's services to TAPR, his support of the HPSDR project, and encouragement of joint activities with AMSAT are remembered. AMSAT extends its condolences to his family and the TAPR community for their loss.

AMSAT Lab: Discussions continue with the University of Florida regarding establishment of the AMSAT Lab on campus. A draft MOU has been circulated with revisions made by both parties. A critical area of discussion right now is the question of Intellectual Property Policy and how UF's current policy might impact AMSAT activities on the UF campus. While AMSAT's current policy will clearly apply to individuals who develop intellectual property under AMSAT sponsorship, there is a question of how UF's policy would apply to students and other individuals who have an affiliation with Florida and how their volunteer efforts on behalf of AMSAT would fit under UF's Intellectual Property Policy. I mention this to highlight the degree of detail that these discussions have generated and that we are mindful of the lessons learned from our prior experiences in the placement of the AMSAT lab. I continue to hopeful that

a final agreement will be negotiated soon.

ITAR: AMSAT is still awaiting response from the US State Department's Directorate of Defense Trade Controls (DDTC) regarding our Advisory Opinion (AO) request that was submitted in early December 2009. Our request is centered upon what constitutes public domain and to seek clarification on how best for AMSAT to maintain our work in the public domain so that we abide by current law, but still have an outlet for sharing technical information with other AMSAT organizations without the need to seek a Technical Assistance Agreement.

2010 Dayton Hamvention: Plans are developing for the Dayton Hamvention, 14-16 May 2010. We are awaiting confirmation of the amount of time for the AMSAT Forum. We do anticipate involvement with the SUNY-Binghamton Systems Engineering students who are developing their 'next generation' CubeSat design as part of our program.

AMSAT has a block of rooms reserved at a different hotel than where we've stayed for the past five years. This year we'll be at the Country Inn & Suites, 3971 Colonel Glenn Highway, Fairborn, OH 45324. Those individuals interested in assisting in the manning of the AMSAT booth and would like to reserve a room should contact AMSAT's manager, Martha Saragovitz, as soon as possible.

The joint AMSAT-TAPR dinner will again take place Friday evening at the Kohler Presidential Banquet Center, Kettering, OH (just south of Dayton). This is the same location as in 2008 and 2009. This year TAPR is arranging for our banquet speaker and as of this writing, a speaker has not yet been announced. AMSAT will be coordinating banquet reservations. Stay tuned for more details.

Dayton is always an exciting time for AMSAT, and I look forward to meeting you at Hamvention.

2010 AMSAT Symposium: The 2010 AMSAT Symposium will take place 8-10 Oct 10 at the Holiday Inn, Elk Grove, IL. This is the same hotel where the joint ARRL-TAPR Digital Communications Conferences in 2008 and 2009 and the 2009 Central States VHF Conference were held. This hotel has received high marks for how these conferences were conducted, including the Audio/Visual services provided by an amateur who performs these services

professionally. This same amateur will provide similar services for the AMSAT Symposium as well.

Please mark your calendar for the Symposium, which should be a great time for AMSAT members in the Midwest to join us and have an opportunity to enjoy the hospitality extended in the Windy City.

Regards,

Barry Baines, WD4ASW

President-AMSAT ☸

K4T in the Field





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Units will be shipped as they become available.

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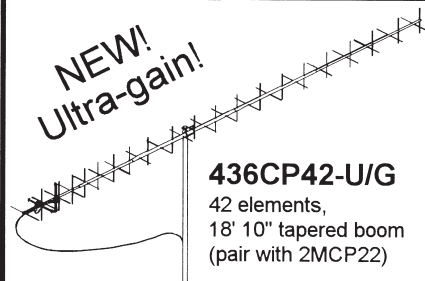
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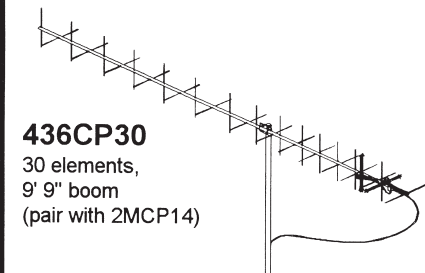
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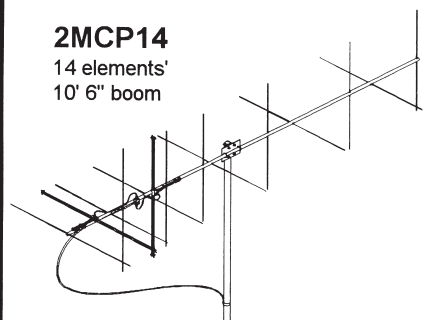
436CP42-U/G

42 elements,
18' 10" tapered boom
(pair with 2MCP22)



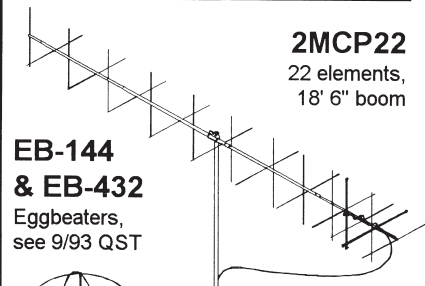
436CP30

30 elements,
9' 9" boom
(pair with 2MCP14)



2MCP14

14 elements'
10' 6" boom

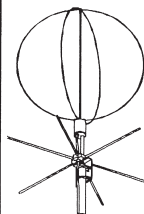


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GcmWin Software by SM3GSJ Global Grid Square Visualization Tool

John, K8YSE, posted a map showing the map of the at least 86 different grids worked by Jim, ND9M, during his recent 6-week road trip. John says the red grids are ones that he worked ND9M in and blue grids are the ones he missed. See: <http://www.papays.com/nd9m.jpg>

John wrote, "I've received several inquiries about the software that was used to create the ND9M/p road trip grid square plot.

The program is a Great Circle Map generator with some very nice features created by SM3GSJ. KD8CAO originally discovered this program and posted info about it on the amsat-bb. It is called GcmWin." Roger, SM3GSJ, has added some functionality that makes it very suitable for those who chase grids. Originally, to plot grid square data, a 6 character grid designation was required. Roger changed it so that 4 character grids were acceptable.

In addition, only one set of grid square data could be overlayed on the map. He graciously changed the software so that two different colors from two different grid square files could be plotted. Now you can show your confirmed grids in one color and your worked grids in another. The program has many other features related to propagation that might interest those who work HF. The homepage for the software is: <http://www.qsl.net/sm3gsj/>

John is thinking about creating a Web page that could be used as a repository for posting these maps for anyone that is interested in having their plot on line. Let him know if you're interested. You can view his plot at: <http://www.papays.com/k8ysegrids.jpg>. In that plot John set the radius at 8200 miles which is a compromise between detail and the maximum distance that can be worked on AO-7. If you decrease the radius, more detail can be shown. You can include grid square numbers if you make the radius small enough. Red is confirmed and blue is worked.

[ANS thanks John, K8YSE for the above information] ☺

Help Wanted

AMSAT needs qualified volunteers for a number of positions!

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- Project management
- Documentation
- Hardware testing
- Software testing
- Hardware prototyping
- Specific area Web site information maintenance
- Video recording, digital conversion and editing
- Write technical or instructional material
- Educational activities
- Promoting AMSAT as an Area Coordinator



and any other area you think you think you can make a difference.

We often have people volunteer, but many don't deliver on their promises. So, pick an area that you think needs improvement and explain what you will do to make it better. Then do something to show that you can follow through.

Send your suggestions, actions plans and a description of why you are capable of doing this task to Gould Smith, WA4SXM, wa4sxm@amsat.org

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- ✓ Annual endorsement sticker after each year of donation.

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FCC to Permit Rescue Radio Robot in the 430 to 450 MHz Band

Reports initially carried in the February 26, 2010 edition of Amateur Radio NewslineT Report 1698, and on the QRZ.com Web site say the FCC has issued a waiver of the Part 90 rules to permit a company called Reconrobotics Incorporated to sell a remote controlled security robot that will operate in the 430 to 448 MHz band. This is spectrum that is primary to the Federal Radiolocation Service, but also encompasses the Amateur Service weak signal, satellite and repeater subbands.

The waiver permits Reconrobotics to manufacture and sell a device called the Recon Scout. This is described as a device designed for state and local law enforcement and firefighting agencies and security personnel in critical infrastructure industries. The Recon Scout can be thrown, dropped, or launched into potentially hazardous areas and can provide real-time video to an operator located a safe distance away. Typical applications will include such things as checking a building prior to forced entry, searching vehicle undercarriages for explosives and searching for survivors in a burning structure.

The Recon Scout transmits the analog video signal to the operator on one of three six megahertz channels. These are 430 to 436 MHz, 436 to 442 MHz and 442 to 448 MHz. Reconrobotics says that multiple channels are necessary in order to avoid interference during incidents where multiple Recon Scouts are in use, but that such situations should be rare.

The company's now approved proposal is that the first unit sold to a responding organization would operate on 442 to 448 MHz. That happens to be where thousands of ham radio repeaters operate. The 436 to 442 MHz version being sold only to entities that already own the 442 to 448 MHz version, and the 430 to 436 MHz version being sold only to entities that already own both of the others.

In approving the waiver, the FCC told Reconrobotics the Recon Scout will have to operate on a secondary basis where it cannot cause interference and is not protected from interference to all Federal users and licensed non-Federal users including radio amateurs. The FCC also warned prospective users that operation of the Recon Scout in an unauthorized manner will subject

licensees to Commission enforcement action and license revocation. It also said that widespread improper use of the device could lead the Commission to stop granting or renewing Recon Scout authorizations.

[ANS thanks Amateur Radio Newsline Report 1698 for the above information]

SK: Dave Toth, VE3GYQ

AMSAT received the sad news of the passing of a friend noting the passing of Dr. David Toth, VE3GYQ. Dave was the President Emeritus of Tucson Amateur Packet Radio (TAPR) Group. He was an early member of TAPR, a long time supporter of AMSAT and he gave of his time and talents to promote technical endeavors in Amateur Radio. Former AMSAT President Tom Clark, K3IO, remembered Dave;

"He was always a friend of AMSAT, giving up personal vacations to help with the integration of AO-40 in Orlando. For many years, he was the glue that held TAPR together."

Former AMSAT board member, Bob McGwier, N4HY, recalled that, "Dave was an important player in the earliest days of packet radio in that he helped promote packet and supported it with on the air hardware.

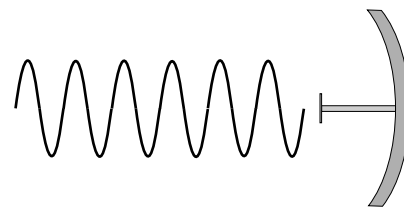
As a board member and president of TAPR, he helped TAPR become the principal support for Open HPSDR, a project to promote the development of hardware and software for software defined radio use by Amateur Radio. He will be sorely missed by all who knew him."

Dr. Toth graduated from the University of Western Ontario Medical School in 1978. He practiced family medicine in London, Ontario but moved to the U.S. in 1993 to began a career in emergency medicine. He was a partner of Premier Health Care Services, in Dayton, Ohio and worked at Lima Memorial Health System and St. Rita's Medical Center until the time of his illness.

[ANS thanks Tom Clark, K3IO; Bob McGwier, N4HY; Steve Bible, N7HPR; ARRL, TAPR and Amateur Radio Newsline for the above information]

AO-51 Survives Close Encounter With FORMOSAT-3

AMSAT-NA VP Operations, Drew, KO4MA, received notification from the US Joint Space Operations Center, located at Vandenberg Air



Force Base, California on Sunday, February 28 warning that AO-51 would have a close approach to another satellite, FORMOSAT 3-D, on Monday at 1056 UTC. This occurred over the Eastern US, with many stations on hand capable of receiving telemetry from AO-51 before and after the near miss. Drew said, "The predicted miss distance was 953 meters, which is over 3000 feet overall but the radial difference between the two orbits was only 39 meters."

Steve, W3HF, noted, "Given the orbital uncertainties of both satellites, an orbit separated by only 39 meters could mean that distance might be eaten up rather quickly!"

In preparation for the close encounter, Drew shut off the S band transmitter and turned on the digital downlink at 2 watts, with telemetry transmitted every 5 seconds. The next morning, on March 1, Drew was able to post a message that AO-51 was alive and well, "It looks like we are fine. A second warning e-mail this morning from the Air Force called it even closer, but everything was working at LOS this pass."

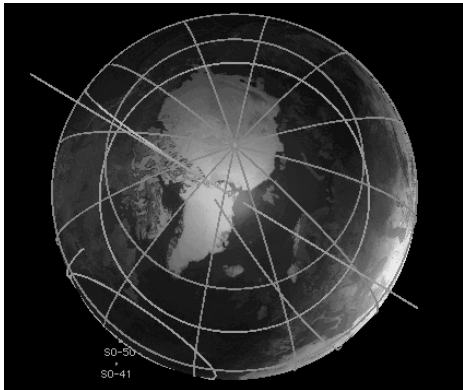
FORMOSAT-3 is a constellation of satellites launched on April 15, 2006. It is a joint U.S.-Taiwanese project with major participants including the University Corporation for Atmospheric Research (UCAR), the National Science Foundation, the Naval Research Laboratory (NRL), the Air Force Research Laboratory (AFRL) on the U.S. side and the National Space Organization (NSPO) on the Taiwanese side.

[ANS thanks AMSAT-NA VP Operations, Drew, KO4MA, and Steve, W3HF, for the above information] 🌐



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2010 AMSAT Field Day Competition

by Bruce Paige, KK5DO, kk5do@amsat.org

It's that time of year again; almost summer and Field Day! Each year the American Radio Relay League (ARRL) sponsors Field Day as an emergency preparedness exercise. The event takes place during a 24-hour period on the fourth weekend of June. For 2010 the event takes place during a 27-hour period from 1800 UTC on Saturday June 26, 2010 through 2100 UTC on Sunday June 27, 2010. Those who set up prior to 1800 UTC on June 26 can operate only 24 hours. The Radio Amateur Satellite Corporation (AMSAT) promotes its own version of Field Day for operation via the amateur satellites, held concurrently with the ARRL event.

If you are considering ONLY the FM voice satellites like AMSAT-OSCAR 16, AMRAD-OSCAR-27, SaudiSat-Oscar-50, or AMSAT-OSCAR-51 for your AMSAT Field Day focus, don't unless you are simply hoping to make one contact for the ARRL rules bonus points. The congestion on FM LEO satellites was so intense in prior years that we must continue to limit their use to one QSO per FM satellite. This includes the International Space Station. You will be allowed one QSO if the ISS is operating voice. You will also be allowed one digital QSO with the ISS or any other digital, non-store-and-forward, packet satellite (if operational).

The format for the message exchange on the ISS or other digital packet satellite is an unproto packet to the other station (3-way exchange required) with all the same information as normally exchanged for ARRL Field Day,

e.g.:

W6NWG de KK5DO 2A STX

KK5DO de W6NWG QSL 5A SDG

W6NWG de KK5DO QSL

If you have worked the satellites on Field Day in recent years, you may have noticed a lot of good contacts can be made on some of the less-populated, low-earth-orbit satellites like Fuji-OSCAR 29 (may or may not be operational) and AMSAT-OSCAR 7. During Field Day the transponders come alive like 20 meters on a weekend. The good news is that the transponders on these satellites will support multiple simultaneous contacts. The bad news is that you can't use FM, just low duty-cycle modes like SSB and CW.

THE 2010 AMSAT FIELD DAY RULES

The AMSAT Field Day 2010 event is open to all Amateur Radio operators. Amateurs are to use the exchange as specified in ARRL rules for Field Day. The AMSAT competition is to encourage the use of all amateur satellites, both analog and digital. Note that no points will be credited for any contacts beyond the ONE allowed via each single-channel FM satellite. Operators are encouraged not to make any extra contacts via these satellites (Ex: AO-27 & SO-50). CW contacts and digital contacts are worth three points as outlined below.

1. Analog Transponders

ARRL rules apply, except:

- Each phone, CW and digital segment ON EACH SATELLITE TRANSPONDER is considered to be a separate band.
- CW and digital (RTTY, PSK-31, etc.) contacts count THREE points each.
- Stations are limited to one (1) completed QSO on any single channel FM satellite. If AO-51 has the V/U and L/S modes turned on, one contact each is allowed. If the PBBS is on (see Pacsats below), ISS (1 phone and 1 digital), Contacts with the ISS crew will count for one contact if they are active. PCSat (I, II, etc.) (1 digital),
- The use of more than one transmitter at the same time on a single satellite transponder is prohibited.

2. Digital Transponders

For the Pacsats (GO-32, AO-51) or 'Store and Forward' hamsats, each satellite is considered a separate band. Do not post "CQ" messages. Simply upload ONE greeting message to each satellite and download as many greeting messages as possible from each satellite. The subject of the uploaded file should be posted as Field Day Greetings, addressed to ALL. The purpose of this portion of the competition is to demonstrate digital satellite communications to other Field Day participants and observers. Do not reply to the Field Day Greetings addressed to ALL.

The following uploads and downloads count as three-point digital contacts.

- (a) Upload of a satellite Field Day Greetings file (one per satellite).

- (b) Download of Satellite Field Day Greetings files posted by other stations. Downloads of non-Field Day files or messages not addressed to ALL are not to be counted for the event. Save DIR listings and message files for later "proof of contact."

Please note AMSAT uploaded messages do not count for QSO points under the ARRL rules.

Satellite digipeat QSO's and APRS short-message contacts are worth three points each, but must be complete, verified two-way exchanges. Remember, only one digipeat contact is allowed for the ISS and other satellites in this mode.

The use of terrestrial gateway stations or Internet gateways (i.e. EchoLink, IRLP, etc.) to uplink/downlink is not allowed.

Sample Satellite Field Day Greetings File:

"Greetings from W5MSQ Field Day Satellite station near Katy, Texas, EL-29, with 20 participants, operating class 2A, in the AMSAT-Houston group with the Houston Amateur Television Society and the Houston QRP club. All the best and 73!"

Note that the message stated the call, name of the group, operating class, where they were located (the grid square would be helpful) and how many operators were in attendance.

3. Operating Class

Stations operating portable and using emergency power (as per ARRL Field Day rules) are in a separate operating class from those at home connected to commercial power. On the report form simply check off Emergency or Commercial for the Power Source and be sure to specify your ARRL operating class (2A, 1C, etc.).

AND FINALLY...

The Satellite Summary Sheet (see next page) should be used for submission of the AMSAT Field Day competition and be received by KK5DO (e-mail or postal mail) by 11:59 P.M. CDT, Monday, 12 July 2010. The preferred method for submitting your log is via e-mail to kk5do@amsat.org or kk5do@arrl.net.

You may also use the postal service but give plenty of time for your results to arrive by the submission date. Add photographs or other interesting information that can be used an



article for the Journal.

You will receive an e-mail back (within one or two days) from me when I receive your e-mail submission. If you do not receive a confirmation message, then I have not received your submission. Try sending it again or send it to my other email address.

If mailing your submission, the address is:

Bruce Paige, KK5DO

Director of Awards and Contests

P.O. Box 310

Alief, TX 77411-0310.

Certificates will be awarded to the first-place emergency power/portable station at the AMSAT General Meeting and Space Symposium in October, 2010. Certificates will also be awarded to the second and third place portable/emergency operation in addition to the first-place home station running on emergency power. Stations submitting high, award-winning scores will be requested to send in dupe sheets for analog contacts and message listings for digital downloads.

You may have multiple rig difficulties, antenna failures, computer glitches, generator disasters, tropical storms and there may even be satellite problems, but the goal is to test your ability to operate in an emergency situation. Try different gear. Demonstrate satellite operations to hams that don't even know the hamsats exist. Test your equipment. Avoid making more than ONE contact via the FM-only voice hamsats or the ISS, and enjoy the event! 🌐

AMSAT Satellite Summary Sheet - 2010

Satellite and number of Voice QSO's

AO-27 1 (example)

Satellite and number of CW/RTTY/PSK31 etc QSO's

AO-07 5 (example)

Satellite and Up/Downloads

UO-11 3 (example)

Score Calculation

Total Voice QSO's x 1 = 1

Total CW/RTTY/PSK31 QSO's x 3 = 15

Total Up/Downloads x 3 = 9

Grand Total = 25

Please provide the following information

Your Field Day Callsign:

Your Group Name:

ARRL Field Day Classification:

ARRL Section:

Power Source (Select 1)

Emergency

Commercial

Your name and home call:

Home address:

Any Comments:



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by Keith Pugh, W5IU
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by Daniel Schultz, N8FGV
- AO-7's Solar Power Array Power After 35 years in Orbit
by James A. DeYoung, N8OQ
- Software Radio Technology on ARISSat-1
by Anthony Monteiro, AA2TX
- AMSAT NextGen Satellite Project
by the NextGen Satellite Team and Alex Harvilchuck
- AMSAT Eagle - Building a Mission for Education
by JoAnne Maenpaa, K9JKM
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by Stephen Hicks, N5AC, Greg Jurrens, WD0ACD, and Ken Simmons K5UHF

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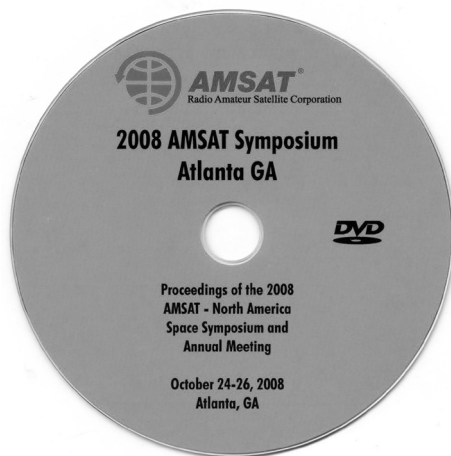
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"Go West, Young Man." by George Carr, WA5KBH, wa5kbh@amsat.org

The now infamous 1865 instruction "Go west, young man," you will likely recall, is credited to Andrew Greeley, the founder and editor of *The New York Tribune*. (In fact, he only misquoted John Soule, who used the quote as the lead in his 1851 *Terre Haute Express* editorial. The exact quote is, "Go West, young man, and grow up with the country.") This autumn, several of the regular users of AO-51 once again misquoted Greeley when they instructed me to, "Go north, young man." (At 60 years old, I am still a young man. Right?)

With no one operating from EM31 on a regular basis, several hams needed that grid for their VUCC. (Actually, I do, too!) So, within a few weeks of the request, off I went on a Thursday late afternoon north from EM30 to EM31. Several minutes into EM31 (see Figure 1), I noticed a vocational-technical school on the west side of U.S. 171. Within a minute or so, I spotted a cross-over and made a U-turn to return to the vo-tech school entrance. I drove up the slight incline and through the open security gate. Once inside and near the sole building, I noticed two men sitting on the steps of the building. I told them what I wanted to do and asked if they minded ... and equally importantly if the gate would remain unlocked so I could return home that evening!

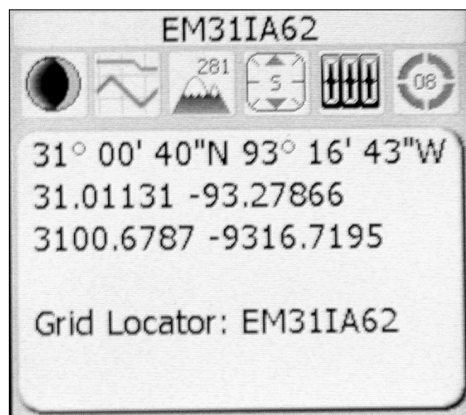


Figure 1: GPS display from EM31.

As it turned out the older man told me he was the electronics instructor and the younger man was his student! After I parked and showed off the Arrow II antenna, Icom W32A, micro-tape recorder and sat pass schedule, the instructor sent the student inside the building to get another student who was in the process of completing an

exam. All three men seemed interested and were able to witness several contacts on both AO-51 and SO-50.

A week and a few days later, on a Saturday afternoon, I answered the next call, this time to "Go, south, young man!" So I headed south and I travelled from EM30 to EL39.

The travel distance from my QTH in EM30 to my destination in EL39 (see Figure 2) was a bit more than 60 miles roundtrip, so it was not a killer. I had to drive on several miles of two-lane highway, crossing from my own Calcasieu Parish into Cameron Parish (in Louisiana our political subdivisions are not counties, but parishes). I passed over a pontoon bridge, that fortunately was not open to boat traffic when I passed, and continued on the two-lane road. As I drove, it was very evident and saddening to still see the tops of trees snapped off and still much debris piled along the roadway. There were also places where homes once stood from Hurricanes Rita (2005) Gustav and Ike (2008). The few homes that have been rebuilt are all on 12 to 14-foot pilings, as parish building-code designers are anticipating the return of high (as in 12-foot) storm surges from the sometimes reckless and merciless Gulf of Mexico once again during some future hurricane season. (Many people have not rebuilt as evidenced by the Sunday participation in Catholic Mass – about one-quarter of the pre-hurricanes census.)

I was able to get there in time for the AO-27 pass, which I had not expected. As it turned out that was the best of the three satellite passes that afternoon.

During this trip, I made contact with 12 stations. (My original plan was to walk out 500 feet over the water, to the end of a pier and operate to potentially benefit from the saltwater reflector. But, that was not to be that day.) I did locate myself on the second floor porch of a home belonging to a co-worker on Big Lake, about 10 minutes south of the EM30-EL39 border. Thuy, my co-worker, was fascinated with the idea of talking through the hamsats and readily volunteered to be the rotor for my Arrow II. (See Photo 1)

As a sideline to this story, Thuy came to the United States at 18 years of age as a refugee with the other boat people from Viet Nam (1975), fleeing from the Communists.

They came with literally nothing but hope and the clothes on their backs, packed into small boats, until they reached international waters where commercial ships picked them up from manmade platforms. From there, they were brought to refugee camps in The Philippines and in Guam, before reaching the mainland of the United States. Now married with adult children, Thuy and her husband, Duc, fixed me fish soup using Vietnamese spices and specially prepared fish. This was followed by the main course of roasted duck and a different recipe for fish soup.

On this trip, I had hopes of going fishing off the pier, as there are bountiful redfish, flounder, trout and catfish in the saltwater Big Lake, but my hips were giving me a great deal of pain so I thanked my host and hostess and returned home to rest.

I detail these two grid-expeditions to you to illustrate how easy it is to venture out not too far from the comforts of your usual QTH to give out grids that other grid chasers might need.

I would also like to call attention to a difficulty. Many of us who travel, travel light, without much power. Please listen and if you do hear someone sign "/portable" or "/handheld", we are probably running a handie talkie and maybe squeaking out 4-5 watts. And, obviously we are at a disadvantage to those operating comfortably (meaning warm

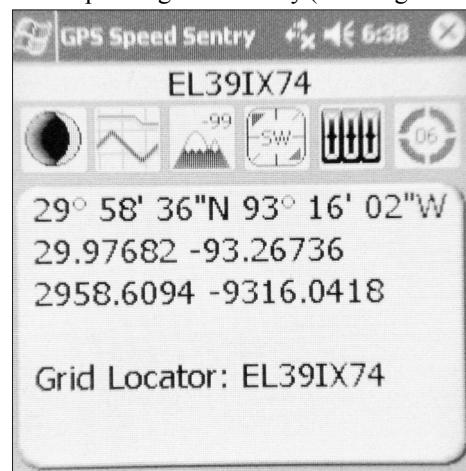


Figure 2: GPS display from EL39.

in the winter and for sure out of the rain or snow!) from their home QTH, operating with higher gain antennas and considerably more power.

Please cut us some slack as we are there at the request of others who do need to

work these grids. Listen. Allow others to work us. We ask and also appreciate your cooperation.

There have been several hams that have done what I have done and have gone to much farther locales and for greater periods of time. To these, I say “thank you” for literally going the extra mile for us!

To those working on VUCC or its endorsements, Happy Hunting! 🌐



Photo 1: WA5KBH (left) works a satellite pass with antenna guidance from Thuy, a co-worker, who provided the location in EL39 – on Big Lake, in Cameron Parish, Louisiana. The floor of the porch is 23 feet above mean sea level (msl), a combination of the ground being built up considerably and the pilings to support the home, which is very high for this area!

Hamfest Season!



Patrick, WD9EWK, conducting a satellite demonstration using VO-52 at the Yuma, AZ hamfest on Saturday, 20 February 2010.



The crew that assisted Patrick, WD9EWK, with the AMSAT table for the Yuma hamfest in February. Left to right: Antonio XE2SIV; Larry KI6YAA; Eliseo XE2TPJ; Alex, XE2BSS/N2IX; Kevin, KJ6DDS. All 5 live in the Yuma area, all are satellite operators. Kevin was on the radio for a couple of demonstrations during the afternoon of Saturday, 20 February 2010, at the Yuma hamfest.



Successful AMSAT Activities at the 2010 Greater Houston Hamfest

by Allen F. Mattis, N5AFV, n5afv@amsat.org

AMSAT was well represented again this year at the Greater Houston Hamfest (GHH) held March 6, 2010 at the Fort Bend County Fairgrounds in Rosenberg, Texas, southwest of Houston. The GHH is billed as the fastest growing hamfest in Texas and this year the GHH again hosted the American Radio Relay League (ARRL) South Texas Section Convention. ARRL Regulatory Information Manager Dan Henderson, N1ND, and ARRL West Gulf Division director Dr. David Woolweaver, K5RAV, were the featured speakers. The GHH had all of the usual hamfest activities including over 18,000 square feet of indoor exhibit space, tables for vendors and individuals, a free tailgate area with early buyer access before the main hall opened, Amateur Radio related presentations and exhibits, and VE testing sessions.



Figure 1: Entrance to the 2010 Greater Houston Hamfest.

The AMSAT booth was manned by Mike Scarcella, WA5TWT, and his team consisting of Andy MacAllister, W5ACM, Tom Matthews, K5SAF, Charlie Keng, K5ENG, Scott Kendall, WA5LHM, Tony Summerville, N5RPQ, Louis House, KD5GM, and Pete Abad, KD5ELH.

Allen Mattis, N5AFV, presented a talk entitled "More OSCAR Satellites Active



Figure 2: Mike, WA5TWT, and his team gathered around the AMSAT booth (photograph by W5ACM)

Today than Ever Before" that was attended by 45 people. At the conclusion of the talk, questions from the audience were answered and a satellite demonstration team consisting of Will Thomas, N5ESA, George Carr, WA5KBH, Jim Clary, ND9M, Andy MacAllister, W5ACM, Louis House, KD5GM, Walter Holmes, K5WH, and Allen Mattis, N5AFV, walked the attendees out into the parking lot for a Saudi-OSCAR-50 pass. Will and George made contacts using the special event call sign W5H issued for the hamfest while the other members of the team were scattered among the spectators providing everyone with an opportunity to hear the satellite. Arrows, Elks, Pryme AL-800s and other curious, homebrew, hand-held antennas were everywhere. Over 85 people attended the two satellite demonstrations and approximately 20 contacts were made.

The Brazos Valley Amateur Radio Club (BVARC), organizer of the hamfest, fully supported the AMSAT activities again this year by giving away a Kenwood TH-F6A HT, Arrow antenna and duplexer as the raffle second prize at the hamfest. Many favorable comments from attendees regarding the AMSAT activities were received by the hamfest organizers. 📶



Figure 3: View of Greater Houston Hamfest main floor from AMSAT booth.



Figure 4: Walter, K5WH, and Louis, KD5GM, preparing for satellite demonstration (photograph by Travis Burgess).



Figure 5: Will, N5ESA, preparing for a satellite demonstration (photograph by WA5KBH).

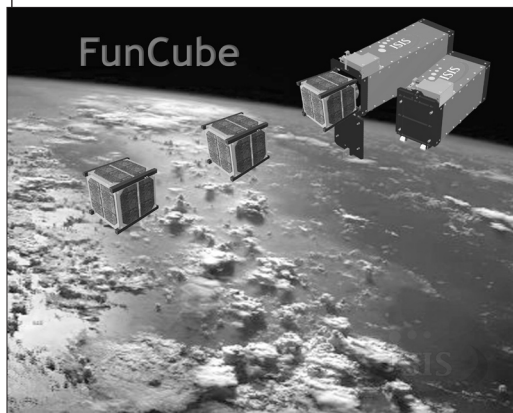


Figure 6: Jim, ND9M, George, WA5KBH, Allen, N5AFV, and Andy, W5ACM, chatting after a successful satellite demonstration.

AMSAT-UK FUNcube Press Notice

AMSAT-UK has announced a new amateur satellite project - FUNcube. The project has received major initial funding from the Radio Communications Foundation (RCF) and is expected to be developed in collaboration with ISIS-Innovative Solutions in Space BV.

FUNcube is an educational single CubeSat project with the goal of enthusing and educating young people about radio, space, physics and electronics. It will support the educational Science, Technology, Engineering, Maths (STEM) initiatives and provide an additional resource for the



FUNcube deployment

GB4FUN Mobile Communications Center. The target audience consists of primary and secondary school pupils. FUNcube will feature a 145 MHz telemetry beacon that will provide a strong signal for the pupils to receive. It is planned to develop a simple receiver board that can be connected to the USB port of a laptop to display telemetry in an interesting way. The satellite will contain a materials science experiment, from which the school students can receive telemetry data which they can compare to the results they obtained from similar reference experiments in the classroom.

FUNcube is the first CubeSat designed to benefit this group and is expected to be the first UK CubeSat to reach space.

It is anticipated FUNcube will be launched into a Sun Synchronous Low Earth Orbit about 600-700km above the earth using one of the many launch opportunities that exist for CubeSat missions. In such an orbit the satellite passes over Europe approximately 3 times in the morning, and 3 in the evening, every day, perhaps allowing the morning passes to be used for educational purposes



FUNcube tracking

and the evening passes for Amateur Radio communications.

FUNcube will carry a UHF to VHF linear transponder that will have up to 1 watt RF output and which can be used by radio amateurs worldwide for SSB and CW communications. Measuring just 10 x 10 x 10 cm, and with a mass of less than 1kg, it will be the smallest ever satellite to carry a linear transponder and the choice of frequencies will enable radio amateurs to use their existing VO-52 or DO-64 station.

A key feature of the satellite is the absence of an on-board computer. For reliability and maximum power efficiency, the design has been kept as straight-forward as possible with satellite control being achieved using simple commands.

AMSAT-UK has more than 350 individual members and is one of more than 20 such groups worldwide. AMSAT-UK teams have provided hardware for more than 10 satellites over the past 35+ years including SSETI Express in 2005. They are presently involved with the development of hardware and software for a number of satellite projects including the European Student Earth Orbiter (ESEO), P3E, SUITSAT2, the Columbus module on the ISS and also the GENSO Ground station network.

The Radio Communications Foundation is a Registered Charity (Number 1100694) set up in 2003 to fund efforts to bring the wonders

of radio into the classrooms, universities and any other public place where hands on demonstration can influence understanding. The RCF funding for FUNcube is made possible through the generous bequest from a silent key who wanted the hobby that he loved brought to the attention of others. Anyone wanting to make a bequest in their will so that their name can live on in the hobby, or anyone simply wanting to make a donation, should click on the links below.

AMSAT-UK: <http://www.uk.amsat.org/>

Radio Communications Foundation: <http://www.commsfoundation.org/>

GB4FUN: <http://www.gb4fun.org.uk/>

FUNcube contact: Graham Shirville, G3VZV, Tel: +44 (0)7713 665725



FUNcube with GB4FUN



Reach for the stars.

N3UC, formerly N4USI, control operator of AO-27, says, "AO-27 may be getting old and failing at times, after 15 years circling the earth. But, my IC-910H that I use to control AO-27, using data transmissions, has never failed me".

Icom 910H The perfect satellite rig.



Have fun communicating with these satellites using the IC-910H:

AO-27, SO-50, AO-51, and VO-52.

In the near future, check out these satellites:

AMSAT-Phase 3E, AMSAT-Eagle, SumbandilaSAT, and KiwiSAT.

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